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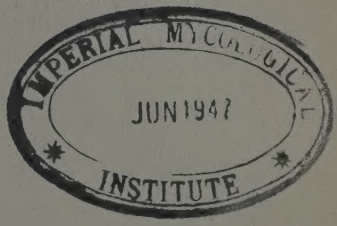

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MATHEMATICS

ON SOME ARITHMETICAL INVARIANTS OF AN ARBITRARY MATRIC LIE ALGEBRA

By G. B. GUREVICH

(Communicated by A. N. Kolmogoroff, Member of the Academy, 9.III. 1944)

In my papers ([1], [2]) I have shown for trivectors in a space of dimension 7 or 8 systems of arithmetical invariants that determine completely the type of these trivectors. In the present paper I construct analogous systems of numerical invariants for any matric Lie algebra in a space of arbitrary dimension. In view of the well-known connexion between Lie groups and Lie algebras and by virtue of Ado's theorem ([3]) these invariants will undoubtedly prove to be very useful for the problem of classification of all Lie groups. To begin with some preliminary notions are to be introduced.

By a null-algebra we mean a Lie algebra $\mathfrak{A}$ consisting of the matrices of an n-dimensional space E, whose lateral roots are all zero. Such a Lie algebra is necessarily nilpotent. Hence, by theorems due to Engel and Lie, there exists a basis $p_1, p_2, \ldots, p_n$ in the space E possessing the following properties for the first r_1 vectors of this basis

$$Ap_i = 0, \quad i = 1, 2, \ldots, r_1 \tag{1}$$

whenever $A \in \mathfrak{A}$; for the first r_2 vectors

$$A^2 p_i = 0, \quad i = 1, 2, \ldots, r_2 \tag{2}$$

whenever $A \in \mathfrak{A}$, *etc.*

The vectors $p_1, p_2, \ldots, p_{r_k}$ together with all their linear combinations will be said to form the k-th step. The number of all the steps will be denoted by h, so that $r_h = n$.

The equalities (1), (2) and their analogues show that every matrix A of the algebra $\mathfrak{A}$*, being applied to any vector of the space E, carries it into a vector of a lower step. In other words, if in the classification of vectors generated by the null-algebra $\mathfrak{A}$ a vector p belongs to the k-th step, then, for every $A \in \mathfrak{A}$, the lowest step, to which the vector Ap belongs, has an index lower than k. A matrix enjoying this property does not necessarily belong to $\mathfrak{A}$. If the null-algebra $\mathfrak{A}$ contains all the matrices possessing this property with respect to the classification of vectors determined by algebra $\mathfrak{A}$, then it is said to be a complete null-algebra. It is evident that a complete null-algebra not only determines a classification of vectors, but is also itself completely determined by this classification. Consequently, the structure of a complete null-algebra is determined by the system of numbers $r_1, r_2, \ldots, r_h$; the system $|r_h r_{h-1} \ldots r_2 r_1|$ will be called arithmetical characteristics of the complete null-algebra.

In the following I construct an algorithm by means of which a complete null-algebra and the numbers $r_h, r_{h-1}, \ldots, r_1$ are uniquely associated with any

* *I. e.* every linear transformation corresponding to a matrix A.

matric Lie algebra. These r's are the invariants mentioned at the beginning of the paper.

Let $\mathfrak{A}$ be a linear system of matrices. Denote by $\mathfrak{S}$ the normalizer of $\mathfrak{A}$ in the algebra of all matrices of the space. In other words, $\mathfrak{S}$ is the totality of matrices S such that $SA - AS = [SA] \in \mathfrak{A}$, when A belongs to $\mathfrak{A}$.

As is easily seen, $\mathfrak{S}$ is always a Lie algebra. It is evident that $\mathfrak{A}$ is a Lie algebra if and only if $\mathfrak{A} \subset \mathfrak{S}$. The normalizer $\mathfrak{M}$ of a complete null-algebra $\mathfrak{P}$ consists of all those matrices which, in the classification of vectors generated by $\mathfrak{P}$, do not raise the index of the step of any vector. Thus, a matrix M belongs to $\mathfrak{M}$ if and only if M has the following property: if a vector p belongs to the k-th step, then the index to the lowest steps containing Mp does not exceed k.

In this paper I establish the following properties of the normalizer $\mathfrak{S}$ of a linear system of matrices:

α) *Denote by* $\Lambda_1, \Lambda_2, \ldots, \Lambda_n$ *the weights of the normalizer* $\mathfrak{S}$, *i. e. the lateral roots of a matrix* H *belonging to the maximal nilpotent subalgebra of the algebra* $\mathfrak{S}$. *Then the linear relation between the* $\Lambda_1, \ldots, \Lambda_n$ *can be reduced to the form:*

$$\Lambda_i - \Lambda_j = \Lambda_k - \Lambda_l$$

there is no linear relation between $\Lambda_1, \ldots, \Lambda_n$ *and the other elements of* H (*provided that* H *is reduced to a certain canonical form*).

β) *If* $\mathfrak{A}$ *is a null-algebra, then every matrix of its normalizer* $\mathfrak{S}$ *does not raise the index of the step of any vector in the classification of vectors generated by* $\mathfrak{A}$.

In particular, (β) implies:

γ) *If* A *belongs to a null-algebra* $\mathfrak{A}$ *and* S *is an element of the normalizer* $\mathfrak{S}$, *then* $\mathrm{Sp}\,\{SA\} = 0$.

Denote by $\mathfrak{R}$ the set of matrices R such that $\mathrm{Sp}\,\{SR\} = 0$, whenever $S \in \mathfrak{S}$. The set $\mathfrak{R}$ that will be called $\mathfrak{R}$-system of the linear system $\mathfrak{A}$ is a Lie algebra. It follows from Cartan's theory that:

δ) *The* $\mathfrak{R}$-*system of a linear system* $\mathfrak{A}$ *of matrices is a solvable invariant subgroup of the normalizer* $\mathfrak{S}$ *of the system* $\mathfrak{A}$.

Using Theorem α) and basing upon various theorems of Cartan's theory, we obtain the following important result:

ε) *The* $\mathfrak{R}$-*system of any linear system of matrices and, in particular, of any matric Lie algebra, is always a null-algebra.*

The theorems just stated enable us to give the following necessary and sufficient conditions for a linear system of matrices to be a null-algebra (resp., a complete null-algebra):

ζ) *A linear system of matrices is a null-algebra if and only if it is contained in its* $\mathfrak{R}$-*system.*

η) *A linear system of matrices is a complete null-algebra if and only if it coincides with its* $\mathfrak{R}$-*system.*

The further reasoning runs thus. Let $\mathfrak{A}$ be an arbitrary linear system of matrices. Consider the normalizer $\mathfrak{S}$ and the $\mathfrak{R}$-system $\mathfrak{R}$ for $\mathfrak{A}$. By Theorem ε) $\mathfrak{R}$ is a null-algebra. We take the normalizer $\overset{1}{\mathfrak{S}}$ and the $\mathfrak{R}$-system $\overset{1}{\mathfrak{R}}$ for $\mathfrak{R}$. By Theorem ζ) $\mathfrak{R} \subset \overset{1}{\mathfrak{R}}$. It is not difficult to show that $\mathfrak{S} \subset \overset{1}{\mathfrak{S}}$. We then take the normalizer $\overset{2}{\mathfrak{S}}$ and the $\mathfrak{R}$-system $\overset{2}{\mathfrak{R}}$ for the null-algebra $\overset{1}{\mathfrak{R}}$, *etc.* We thus obtain a sequence of Lie algebras

$$\mathfrak{S} \subset \overset{1}{\mathfrak{S}} \subset \overset{2}{\mathfrak{S}} \subset \ldots \subset \overset{k}{\mathfrak{S}} \subset \overset{k+1}{\mathfrak{S}} \subset \ldots$$

and a sequence of null-algebras

$$\mathfrak{R} \subset \overset{1}{\mathfrak{R}} \subset \overset{2}{\mathfrak{R}} \subset \ldots \subset \overset{k}{\mathfrak{R}} \subset \overset{k+1}{\mathfrak{R}} \subset \ldots \qquad (3)$$

If $\mathfrak{A}$ is a Lie algebra, then $\mathfrak{A} \subset \mathfrak{S}$, and, consequently, $\mathfrak{A} \subset \overset{k}{\mathfrak{S}}$ for each k; if $\mathfrak{A}$ is a null-algebra, then $\mathfrak{A} \subset \mathfrak{R} \subset \overset{k}{\mathfrak{R}}$.

As follows from (3), $\overset{k+1}{\mathfrak{R}} = \overset{k}{\mathfrak{R}}$ for k sufficiently large. By Theorem η) $\mathfrak{R}$ is a complete null-algebra. We thus have constructed an algorithm that associates with each linear system of matrices a complete null-algebra $\mathfrak{P} = \overset{k}{\mathfrak{R}}$. Let us formulate the result for the Lie algebras:

ϑ) *It is possible to associate a complete null-algebra* $\mathfrak{P}$ *and, consequently, a system of arithmetical invariants* $\overline{|r_h r_{h-1} \dots r_2 r_1|}$ *with every matric Lie algebra* $\mathfrak{A}$. *If* $\mathfrak{A}$ *is a null-algebra, then* $\mathfrak{A} \subset \mathfrak{P}$. *In the general case* $\mathfrak{A} \subset \mathfrak{M}$, *where* $\mathfrak{M}$ *is the normalizer of the null-algebra* $\mathfrak{P}$.

This theorem singles out from all matric Lie algebras the class of those for which the corresponding complete null-algebra $\mathfrak{P}$ is zero, *i. e.* consists of the unique matrix $P = 0$.

Evidently, this takes place if and only if the $\mathfrak{R}$-system $\mathfrak{R}$ is zero. It is possible to establish that this class coincides with that of completely reducible matric Lie algebras. According to a theorem due to N. Jacobson ([4]), everyone of such algebras is the direct sum of an Abelian and a semi-simple Lie algebras (the converse is not true: even an Abelian group is not necessarily completely reducible). Thus, we have

ι) *A matric Lie algebra is completely reducible if and only if its* $\mathfrak{R}$*-system consists of the unique matrix* $R = 0$.

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REFERENCES

[1] G. B. Gurevich, C. R. Acad. Sci. URSS, III, No. 8—9 (1934). [2] G. B. Gurevich, ibid., No. 5—6 (1935). [3] И. Д. Адо, Изв. КФМО, (2), 7 (1934—1935). [4] N. Jacobson, Annals of Math., 36 (1935).

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MATHÉMATIQUES

SUR LES POLYNÔMES EXTRÉMAUX QUI PRÉSENTENT L'APPROXIMATION D'UNE FONCTION RÉALISANT LA REPRÉSENTATION CONFORME D'UN DOMAINE SUR UN CERCLE

Par A. SCHAGINJAN

(Présenté par S. N. Bernstein, de l'Académie, le 11. II. 1944)

1. Soit D un domaine arbitraire simplement connexe situé dans le plan de la variable complexe z. La fonction $\varphi(z)$ qui réalise la représentation conforme du domaine D sur un cercle dans le plan w jouit d'une propriété extrémale connue. Parmi toutes les fonctions $f(z)$ régulières dans D et vérifiant la condition $f(z_0)=1$, où z_0 est un point à l'intérieur de D, la seule fonction qui rend minimale l'intégrale

$$\iint_D |f(z)|^2\,dx\,dy$$

est la fonction $\varphi'(z)$, dérivée de $\varphi(z)$.

Soit $P_n(z)$ le polynôme extrémal qui rend minimale l'intégrale précédente quand on considère comme admissibles dans le problème du calcul des variations les polynômes $\{Q_n(z)\}$ vérifiant la condition $Q_n(z_0)=1$.

Les polynômes extrémaux sont caractérisés par l'inégalité

$$\iint_D |\varphi'(z)-P_n(z)|^2\,dx\,dy \leqslant \iint_D |\varphi'(z)-Q_n(z)|^2\,dx\,dy \qquad (1)$$

Dans le cas des domaines finis dont le complémentaire est connexe on sait que les polynômes $\{Q_n(z)\}$ peuvent être choisis de telle manière que l'on ait (1):

$$\lim_{n\to\infty} \iint_D |\varphi'(z)-Q_n(z)|^2\,dx\,dy=0 \qquad (2)$$

Alors il résulte de (1) que l'on a

$$\lim_{n\to\infty} \iint_D |\varphi'(z)-P_n(z)|^2\,dx\,dy=0 \qquad (3)$$

Dans le cas général les polynômes extrémaux $\{P_n(z)\}$ convergent en moyenne vers une fonction limite qui diffère de $\varphi'(z)$.

La question se pose de trouver pour les domaines dont le complémentaire n'est pas connexe, ou bien pour les domaines non bornés les conditions pour que l'égalité (3) ait lieu. Nos résultats précédents concernant la recherche des conditions pour qu'un système de fonctions rationnelles dans le domaine complexe soit complet (2) permettent de résoudre ce problème pour certaines classes intéressantes de domaines.

2. Soit D un domaine non borné, simplement connexe, avec un complémentaire connexe, situé à l'intérieur d'une certaine parabole infinie: $y^2=ax$,

$a > 0$. Désignons par $T(\rho)$ la mesure linéaire des arcs que le domaine donné découpe sur la circonférence de rayon ρ et ayant pour centre l'origine des coordonnées.

Théorème 1. *Si l'on a dans le domaine D l'inégalité*

$$\liminf_{\rho\to\infty} \frac{\ln\ln\dfrac{1}{T(\rho)} - \dfrac{1}{2}\ln\rho}{\ln\ln\rho} > 2 \tag{4}$$

l'inégalité (3) *a lieu. Et si*

$$\limsup_{\rho\to\infty} \frac{\ln\ln\dfrac{1}{T(\rho)}}{\ln\rho} < \frac{1}{2} \tag{5}$$

on peut indiquer des domaines pour lesquels

$$\lim_{n\to\infty} P_n(z) \neq \varphi'(z).$$

Par exemple, le domaine borné par l'axe ox, la courbe $y = e^{-x^p}\left(p < \frac{1}{2}\right)$ *et le segment de l'axe oy.*

3. Soit D_1 un domaine infini arbitraire à l'intérieur d'un angle α, topologiquement équivalent à cet angle.

Théorème 2. *Si dans un domaine* D_1 *on a*

$$\liminf_{\rho\to\infty} \frac{\ln\ln\dfrac{1}{T(\rho)}}{\ln\rho} > \frac{\pi}{2\pi-\alpha} \tag{6}$$

l'égalité (2) *a lieu; et si*

$$\limsup_{\rho\to\infty} \frac{\ln\ln\dfrac{1}{T(\rho)}}{\ln\rho} < \frac{\pi}{2\pi-\alpha} \tag{7}$$

cette inégalité, en général, tombe en défaut. Par exemple, dans le domaine borné par deux côtés d'un angle α *et par une courbe qui se trouve à l'intérieur de cet angle et s'approche asymptotiquement à ces côtés, quand* (7) *a lieu l'inégalité* (3) *est impossible.*

Théorème 3. *Si dans un domaine infini situé dans une bande parallèle et topologiquement équivalent à cette dernière on a*

$$\liminf_{\rho\to\infty} \frac{\ln\ln\dfrac{1}{T(\rho)} - \ln\rho}{\ln\ln\rho} > 2 \tag{8}$$

l'égalité (3) *a lieu; et si*

$$\limsup_{\rho\to\infty} \frac{\ln\ln\dfrac{1}{T(\rho)}}{\ln\rho} < 1 \tag{9}$$

(3) *n'a pas lieu. Cette dernière circonstance a lieu, par exemple, pour le domaine borné par les lignes* $y = 0$ *et* $y = e^{-|x|^p}(p < 1)$.

4. Donnons encore la solution du problème posé pour deux classes de domaines finis dont le complémentaire n'est pas connexe.

Pour simplifier les énoncés, soit Δ un domaine simplement connexe borné extérieurement par une courbe fermée de Jordan C_1, et intérieurement par une autre courbe de Jordan C_2 ayant avec C_1 un point commun A. D'ailleurs, Δ est topologiquement équivalent à un domaine borné par deux circonférences tangentes l'une à l'autre.

Supposons qu'en A les courbes C_1 et C_2 ont un point angulaire et possèdent une tangente à droite commune et une tangente à gauche commune, ces deux tangentes formant un angle β. Désignons par $T(\rho)$ la mesure linéaire des arcs

découpés par le domaine Δ sur la circonférence de rayon ρ ayant pour centre le point A.

Théorème 4. *Si*

$$\liminf_{\rho\to 0} \frac{\ln\ln\frac{1}{T(\rho)} - \frac{\pi}{\beta}\,;\frac{1}{\rho}}{\ln\ln\frac{1}{\rho}} > 1 \tag{10}$$

on a dans le domaine Δ *l'inégalité* (3); *et si*

$$\limsup_{\rho\to 0} \frac{\ln\ln\frac{1}{T(\rho)}}{\ln\frac{1}{\rho}} < \frac{\pi}{\beta} \tag{11}$$

l'égalité (3), *en général, n'a pas lieu.*

5. Considérons enfin un domaine B fini simplement connexe dans le plan z que l'on a découpé le long de la droite $(-\infty; 0)$. Supposons que pour $w=\sqrt{z}$ le domaine B se transforme en un domaine à complémentaire connexe. Menons deux droites parallèles à la droite $(-\infty; 0)$ situées des deux côtés de cette dernière et à distance δ de cette droite; leurs extrémités près du point $z=0$ seront réunies par une circonférence de rayon δ. Désignons par $T(\delta)$ la mesure linéaire des arcs que le domaine B découpe sur le contour ainsi formé.

Théorème 5. *Si l'on a en B*

$$\liminf_{\delta\to 0} \frac{\ln\ln\ln\frac{1}{T(\delta)} - \ln\frac{1}{\delta}}{\ln\ln\frac{1}{\delta}} > 1 \tag{12}$$

alors (3) *a lieu dans B; et si*

$$\limsup_{\delta\to 0} \frac{\ln\ln\ln\frac{1}{T(\delta)}}{\ln\frac{1}{\delta}} < 1 \tag{13}$$

(3) *tombe en défaut, en général.*

Donnons un exemple pour le cas où (3) n'a pas lieu. Prenons un point a sur la droite $(-\infty; 0)$. Posons

$$\varphi = \arg(z-a);\ r=|z-a|.$$

Prenons les arcs L_1, L_1' ayant pour équations

$$\frac{2n}{\pi}\sin\varphi\,\frac{1}{r^n} = \pm\frac{\pi}{4}$$

et les arcs L_2, L_2' ayant pour équations

$$\frac{2n}{\pi}\sin\varphi\,\frac{1}{r^n} = \pm\frac{\pi}{2}$$

Ces courbes sortent du point $z=a$ et sont tangentes à l'axe ox. Joignons près de l'origine $z=0$ les extrémités des arcs L_1 et L_2, L_1' et L_2'. Dans le domaine simplement connexe ainsi obtenu, si n est assez grand, (13) est rempli et (3) n'a pas lieu.

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LITTÉRATURE CITÉE

[1] T. Carleman, Arkiv för Mathemat., Astr. och Fysik, 17 (1923). [2] A. Schaginjan, C. R. Acad. Sci. URSS, XLIV, No. 2 (1944).

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ASTRONOMY

ON THE SYSTEM OF WAVE-LENGTHS IN STELLAR SPECTRA

By G. SHAJN, Member of the Academy

For several reasons the problem of the systems of wave-lengths used in astrophysics is far from being satisfactorily solved. In this connexion stars of type O and B, owing to several interesting features, deserve special attention. What we mean here in addition to the general problem of determination of radial velocities is the serious discrepancy in Einstein's red shift, the question of the K term in all its complexity, the systematic motion of gases in stars, atmospheres, the question of the influence of ionic fields on the wave-length of certain spectral lines, *etc.*

For the stars O and B laboratory wave-lengths are used, and a list of primary and secondary standards for this purpose has been recommended by the Commission 30 of the I. A. U. (1). There is no urgent need perhaps for the present to replace the laboratory system by a special one adjusted to stellar lines, but we must take account of all factors that may affect the laboratory system of wave-lengths in its application to stars. In this paper is discussed an effect of blends that previously escaped attention.

Strictly speaking, a considerable majority of lines recommended for O and B stars are blends. Every blend, however, has a predominant component; and it is its wave-length and identification that are tabulated in (1). This way of treating the blends is more or less justified whenever the emission lines satisfy the following conditions: 1) no self-absorption takes place, 2) the predominance of one component is strong enough, say not less than 6 : 1. Sometimes the weighed mean of the components' individual wave-length is used for the effective wave-length of the blend. This appears to be admissible for the emission lines but not for the absorption lines, at least not in all cases. In fact, the discussion of the integral

$$A\lambda = \int_0^{\infty} \left(1 - e^{-NHf}\right) d\lambda$$

well-known in the theory of the curve of growth shows that only in the case of an optically thin layer $\left(\log \frac{NHf}{\Delta\omega_D} < 0.4\right)$ when the total absorption $A\lambda$ is determined by the Doppler widening, will there exist a correspondence between the intensities of emission and absorption lines, or a proportionality between $A\lambda$ and the number of absorbing atoms NHf. If, further, the intensity of the lines is determined by the Doppler widening, as well as by damping radiation, $A\lambda$ changes very slowly as NHf grows. Thus, for $\log NHf/\Delta\omega_D$ ranging within 1.5—3.5, the total absorption increases only about three times as the number of absorbing atoms increases a hundred times. In this case we shall have the maximum discrepancy between the intensity ratio for emission and absorption lines. With a further increase of NHf when the intensities are determined exclusively by the damping radiation, the weight of the fainter component diminishes again. However, as compared to the laboratory ratio f_2/f_1 we shall have $\sqrt{f_2/f_1}$. Unfortunately, the number of undoubtedly single lines in the above-mentioned table is small even for a dispersion of 10 — 30 A/mm. And even these are not all irreproachable for radial velocity work, so the wide hydrogen lines in the absence of a core are often difficult to measure, and moreover, are sometimes affected by the hydrogen emission.

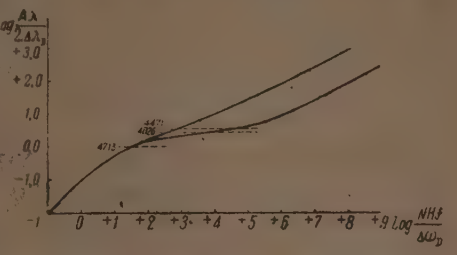
There is also reason to suppose that the wave-lengths of several helium lines are shifted owing to the effect of ionic fields. It is not seldom; especially in the case of three-prism dispersion, that we are using only the lines He 4471 and Mg II 4481, both blends. In practice we are obliged to use blends very often. The question of the effective wave-length of blends must be discussed in detail, and as an illustration may serve the line 4471; which often plays an important rôle in the radial velocity determinations of the stars of type O and B, and also in the study of the Stark effect. The terms $^3P_1$ and $^3P_2$ practicallty coincide, and in the laboratory even at high dispersion only the doublet $2\,^3P_{1,2}{}^0 - 4\,^3D$ (4471.477) and $2\,^3P^0{}_0 - 4\,^3D$(4471.689) is observed. Applying the sum rule to the case where the lines arise from a combination of composite levels, one will obtain for the lines in question an intensity ratio 8 : 1. Something very near to this ratio is actually observed in the laboratory; and at moderate dispersion, when the components are not separated, the fainter one may be neglected. In stellar spectra this pair is observed only as a blend, and there comes up the question of its effective wave-length. What is given for stellar standards in the Table mentioned above (1) are only primaries of the triplets of the diffuse and sharp series, *i. e.* 4026.189, 4471.477, 4713.143... This probably would be more or less true for helium lines in emission. Yet, for absorption lines the theory predicts; as we have seen above, a more essential rôle of the fainter components. In fact; our measurements of several stars of type B revealed a systematic shift of about $+0.04$ Å for 4026; $+0.07$ Å for 4471. The results of other observations also bear witness of considerable positive shift for these lines. Thus, observations by Struve (2); which are more numerous, give for the three lines in question a shift of $+0.045$, $+0.067$ and $+0.106$ Å if only the best plates are considered, and $+0.021$, $+0.087$ and $+0.093$ Å; respectively, if the whole of the material is used.

In order to estimate the effect under consideration it is necessary approximately to know the position of the line on the curve of growth. In the figure the curves of growth are given for two values of the ratio of the damping constant γ to the Doppler width $\Delta\omega_D$ ($a = 10^{-3}$ and $a = 10^{-1}$). The ordinates are adjusted here to $T = 20\,000°$. On the basis of observational data $A\lambda/2\Delta\lambda_D$ the possible position of the helium lines 4026, 4471 and 4713 is indicated on the figure by dashed lines. The figure shows that the lines under consideration really lie within the intermediate branch of the curve of growth; where the effect in question must be very considerable. The result depends to a large extent on the adopted value of $a = \gamma/\Delta\omega_D$. For the classical value of the constant of damping radiation the effect will be stronger. However, there is every reason to believe that owing to the effect of ionic fields, especially in the B dwarfs, the most important factor is collisional damping. The latter for several helium lines may be a hundred times as great as the damping radiation, and in this case the effect of the curve of growth will be sensibly smaller. One may think that for the majority of lines in the spectra of B type $a = 10^{-2}$ is an appropriate value for a. Probably, in all cases the effect of the curve of growth in raising the weight of the fainter components in a blend will be still appreciable.

The observed positive shift in the above-mentioned helium triplet lines seems to be real, and this may be interpreted in terms of the theory of the curve of growth. The usual interpretation of these observations from the point of view of radial velocities will lead to a notable positive excess, which for 4471 amounts to about 5 km/sec. (if the wave-lengths of the above-mentioned Table are assumed). Remember now that because of the rotation nearly half of the B stars have wide diffused lines in their spectra, so that often only the strongest of them are measurable. Nor can hydrogen lines having no core be easily measured. In this case He 4026, He 4471 and Mg II 4481 are the most suitable, and sometimes the only suitable lines for measurement. One may believe that if the wave-lengths of the proposed Table are used, the radial velocities of B stars will; because of the above-mentioned positive shift for the lines of helium triplets, be in the mean affected by systematic error of the order of $+1$ km. This conclusion must not be underestimated, especially if one remembers the serious discrepancy in the relativity shift and other equally interesting effects in the stars of type O and B.

We are faced here with the question of the supposed shift of certain He lines

under the action of ionic fields. The theory of Verweij [3] predicts for the line He 4471, one of the most sensitive to the Stark effect, the very small shift of + 0.01 and + 0.03 Å for $g = 10^2$ and $g = 10^4$; respectively. Keeping in mind, however, the considerable widening of the He lines 4471 and 4026 (≥ 5Å) because of the collisional damping [4] and the presence of forbidden lines 4469.97, 4025.48, mostly not discernible separately and still affecting the position of 4471.477, 4026.189, one may doubt whether this very small shift may be easily observed. In reality the observed shift for 4471 is about 0.07 Å; and this points to the presence of other effects also. If the forbidden line is not properly separated from the main line, the formation of the effective wave-length of a blend, as viewed in the light of the curve of growth, must be under the influence of the components of the triplet, as well as of the forbidden line. The effect of the curve of growth is also to be taken into account when comparing the intensity ratio of the forbidden and main line in the stellar and laboratory spectra.



For the present we have no sufficient data to separate the different effects; in this respect the comparison of the singulets and triplets of different series in the spectra of stars of different luminosity will be very useful. But when the observed shifts are interpreted with reference to the effect of gravitation; or to the effect of ionic field, or to the dynamical phenomena in the atmospheres; the above-mentioned effect of the curve of growth must never be lost sight of.

This effect is of special interest if, as in the case of He triplet, the shift for all lines is of the same sign. But it may be also of importance in the case of blends made-up by different close lines. Most of the lines of the above-mentioned Table recommended for the stars of type O and B are such blends. One of the components; it is true, namely that whose wave-length is given in the Table, is predominant. But if these lines relate to the intermediate branch of the curve of growth, the rôle of the fainter components becomes appreciable. Many of these lines have a total absorption ranging within 0.30–0.80 Å, and at T of about 20 000° they will correspond mainly to the intermediate portion of the curve of growth. For this reason the effective wave-length of the blend in question may differ from the tabulated wave-length. From this point of view the faint lines whose total absorption is less than 0.30 Å, as corresponding to the 45 degree branch of the curve of growth, are most suitable for radial velocity work. One may suppose that hydrogen and helium lines are generally more liable to systematic displacements due to some physical processes in the atmospheres of stars, *e. g.*, in the super-giants. I do not consider here the effect of blends connected with the process of formation of one line within the wing of another line. Thackeray, who discussed this question theoretically, showed that for the line 4471 this effect hardly surpasses 0.02 Å [5].

In the light of the above considerations concerning the blends and the effect of the curve of growth, revision of certain laboratory wave-lengths, as given in the Table for O and B stars and recommended by the Commission of Radial Velocities, seems to be advisable. The theory may help in the selection of the lines for which the effect in question may be appreciable. But the corrections themselves must be immediately derived from the discussion of the observational data. Very likely it will be possible, at least qualitatively, to explain these corrections in terms of the curve of growth and also trace them back to some other effects.

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REFERENCES

[1] Trans. Int. Astr. Union, IV, 186 (1932). [2] O. Struve, Aph. Journ., 74, 225 (1931). [3] S. Verweij, Proc. Netherl. Akad., XLIII, No. 8 (1940). [4] O. Struve, The Observatory, 61, 73 (1938). [5] Trans. Int. Astr. Union, VI, 266 (1938).

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PHYSICS

CALCULATION OF UNKNOWN VIBRATION SPECTRA OF HALOGEN SUBSTITUTED METHANES

By B. I. STEPANOV

(Communicated by S. I. Wawilow, Member of the Academy, 4. IV. 1944)

The values of vibration frequencies for the majority of halogen substituted methanes have been established by Glokler and associates in studying the Raman spectra of these molecules [for literature see (1)]. Only for 8 molecules no data have been available up to the present: CBr_2ClF, $CBrCl_2F$, CBr_2F, $CClF_3$, $CBrF_3$; $CClBrF_2$, $CHBrF_2$; CH_2BrF. Of these the three first molecules have recently been studied by Delwaulle and François (2). Unfortunately, I have not been able to obtain the issue of C. R. containing their paper.

The method of computing the vibration frequencies as suggested by Eliashevich (3-6) makes it possible to predict the spectra of these molecules. The constants of potential energy have been obtained by Stepanov(7) from the frequency values of

Probable Values of Vibration Frequencies

CH_2BrF		$CHBrF_2$		CBr_2ClF		$CBrCl_2F$	
330	A λ	320	A' λ	140	A λ_μ	210	A λ_μ
640	A $q_{Br}\lambda$	380	A $\lambda_\mu q_{Br}$	200	A' λ	230	A' λ
930	A' δ_{Br}	550	A $\lambda_\mu q_{Br}$	220	A λ_μ	270	A λ_μ
1060	A q_F	660	A $q_{Br}\lambda_\mu$	300	A' λ	330	A λ_μ
1200	A' δ_F	1070	A q_F	340	A λq_{Br}	390	A' λ
1340	A $\alpha\delta$	1110	A' q_F	370	A $q_{Br}\lambda$	580	A q_{Br}
1450	A $\alpha\delta$	1300	A δ_F	710	A' q_{Br}	750	A q_{Cl}
2990	A q	1350	A' δ_F	780	A q_{Cl}	780	A' q_{Cl}
3050	A' q	3030	A q	1060	A qF	1060	A q_F

$CBrClF_2$		CBr_2F		$CBrF_3$		$CClF_3$	
200	A λ_μ	140	E $\mu\lambda$	180	E λ	380	E λ_μ
260	A λ_μ	260	A λq_{Br}	340	A $q_{Br}\lambda_\mu$	450	A $\mu\lambda q_{Cl}$
350	A' λ	340	E λ_μ	580	E λ_μ	590	E λ_μ
390	A' λ	440	A q_{Br}	730	A $\lambda_\mu q_{Br}$	750	A $q_{Cl}\mu\lambda$
440	A μq_{Br}	700	E q_{Br}	950	A qF	950	A qF
640	A $q_{Br}\mu$	1070	A qF	1140	E qF	1160	E qF
790	A q_{Cl}						
1070	A qF						
1130	A' qF						

Notations:

q, change of bond length C—H; μ, change of bond angle X—C—X;
q_X » » » » C—X; λ, » » » » X—C—Y;
α, change of bond angle H—C—H; δ_X » » » » H—C—X.

simple halogen derivatives of methane and checked against the frequencies of mixed derivatives known from the experiment. The observed and computed values showed a satisfactory coincidence in the case of 14 molecules, which bears out the correctness of the method.

For molecules not investigated by experiment the vibration frequencies are given in the adjoined table. In its second column are given the symmetry and the main coordinates varying in the course of vibration. The accuracy of the frequency data (about 30 to 50 cm^{-1}) is not very high. But the general character of these complex spectra, which have nearly no characteristic frequencies, is likely to be brought out correctly by this table.

All computations involved in this work have been carried out by S. I. Ryskina.

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REFERENCES

[1] Ta-You-Wu, J. Chem. Phys., 10, 116 (1942). [2] M. L. Delwaulle et F. François, C. R., 214, 828 (1942). [3] M. A. Eliashevich, C. R. Acad. Sci. URSS, XXVIII, 605 (1940). [4] М. А. Ельяшевич, ЖФХ, 14, 1381 (1940). [5] М. А. Ельяшевич, ЖФХ, 15, 847 (1941). [6] М. А. Ельяшевич, ЖФХ, 15, 831 (1941). [7] B. I. Stepanov, C. R. Acad. Sci. URSS, XL, 296 (1943).

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BIOPHYSICS

QUANTITY OF ENERGY NECESSARY FOR VISUAL EFFECT

By N. I. PINEGIN

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The quantum nature of light and the quantum laws of matter determine the character of light absorption. Since no fraction of a quantum can possibly be observed, the possibility of constructing a device that would respond to an energy less than a quantum is out of the question. So the maximum conceivable sensitivity for an ideal device is one quantum.

Our eye is a highly sensitive device. But just how high is its sensitivity? How great should be the least amount of energy in order to produce a visual effect?

There are two methods for measuring this energy — light fluctuation method and straightforward physical method. The method of fluctuations, as developed by S. I. Wawilow ([1–3]), permits the sensitivity of the retina to be measured directly, irrespective of the absorption of light by ocular media.

The straightforward physical method determines the sensitivity of the eye as a whole. Therefore in order to determine the sensitivity of the retina by this method the absorption of light in ocular media must be allowed for. The results obtained by Wawilow with the method of fluctuations are as follows. The one spectator experimented upon in the year 1933 showed for 510 mμ a threshold of visual sensation of 47 photons. In the experiments of 1936 run with two spectators, the threshold, for 510 mμ and a stimulus 30′ in size removed 10° from the fovea, was found to be 8 and 30 photons, respectively.

Finally, in the last tests carried out with four persons the threshold, for 525 mμ and a stimulus 6′ in size removed 8° from the fovea, varied from 18 to 32 photons, making 25 as an average. The minimum number of photons falling upon the pupil under the same conditions varied from 108 to 324, giving thus an average of 208 photons. The last number is approximately 8 times as great as the first. From this it may be inferred that transmission of ligth by ocular media together with the absorption of light in the visual purple makes up about 0.12.

The data the author has obtained by means of straightforward physical measurements are as follows ([10]): they refer to the 491 mμ line lying near the maximum of scotopic sensitivity. For the source of light a mercury lamp was used, whose energy was measured with the aid of a thermopile calibrated against a platinum black body and Hefner's candle. For monochromatization a double spectral decomposition was applied in combination with the use of a filter transmitting no other line but that of 491 mμ and absorbing the stray light.

The measurements were made on 8 spectators, averaging in age from 15 to 37 years, all possessed of a normal vision. There was no fixation of point and the region of the retina involved was the most sensitive parafoveal one, turned reflectively to the stimulus. A dark adaptation for one hour preceded the measurements. In order to eliminate the chromatic aberration of the eye, which for 491 mμ was —1.1 dioptry on the average, negative spectacle lenses of the corresponding dioptries were placed before the eye. The losses of light in the lens were estimated as 10 per cent.

The test-object was a round shape. It was viewed from an angle of 20.9′. The time of observation was not limited.

Each of the spectators was subjected to preliminary training experiments. This training period lasted several days. Then their light threshold was measured by the method of extinction. The measurements were made for monocular vision. For every observer an average of 10 records was computed. The results were expressed in terms of the illumination of the cornea.

The light-flux falling on the retina is

$$F = \frac{E}{h\nu}\sigma$$

where E, erg/sec. cm^2, is illumination on the cornea; $h\nu = 4 \times 10^{-12}$ erg/sec. is energy quantum of monochromatic radiation 491 mμ; $\sigma = 0.44$ cm^2 is the area of the pupil.

In order to determine the energy necessary for visual effect at least three factors; as had been pointed out by Hecht ([13]), are to be taken into account. In the first place, the reflection losses of the cornea, which can be put at 5 per cent; in the second place, the absorption of light by ocular media between the external surface of the cornea and the retina. According to Roggenbau and Wetthauer ([11]), Ludvigh and McCarthy ([12]), this absorption in the region of 500 mμ is about 50 per cent.

Finally, the absorption of light by visual purple must be taken into consideration, for the light not absorbed by it is useless for vision.

An accurate determination of the last quantity presents great difficulties. The conclusion arrived at by Hecht ([13]) from comparisons of the absorption spectrum for different concentrations of visual purple with the curve of scotopic sensitivity is that the absorption coefficient can be put at 20 per cent for 510 mμ.

In the adjoined table are given the energy values necessary for visual effect; they were computed from the illumination on the retina with allowance for the above-mentioned factors.

Quantity of Energy Necessary for Visual Effect

Spectators	Age	E, erg/sec. cm^2	F, quanta/sec.
P. I.	37	3.89×10^{-9}	40.4
S. I.	17	3.58×10^{-10}	3.7
M. A.	21	4.24×10^{-9}	44.1
E. N.	29	6.71×10^{-9}	69.8
D. I.	19	6.10×10^{-9}	63.4
P. G.	22	3.05×10^{-10}	3.2
B. N.	25	1.36×10^{-9}	14.1
K. D.	15	2.78×10^{-9}	28.9
	Average	3.22×10^{-9}	33.5

Comparing these data with those of S. I. Wawilow it should be remarked that the threshold of visual effect in the author's experiments varied within a wider range (3—70 quanta) than in Wawilow's (18—32 photons). Yet the average value of the light threshold in the experiments described here is rather near to the value obtained for the threshold by Wawilow, exceeding it only 1.3 times(33 quanta as against 25 quanta obtained by Wawilow).

It must be borne in mind that the values compared do not refer to equal conditions of experiment and have been obtained by different methods.

Hecht ([13]) performed his measurements partly by the straightforward physical method, partly by the method of light fluctuations used by Wawilow. The measurements were run at 510 mμ for the region of the retina located 20 from the fovea. The dimensions of the test-object were 10′. Straightforward measurements were made on 6 persons. The threshold energy on the cornea was found by Hecht to

range from 58 to 148 quanta, and the quantity of energy necessary for visual effect with allowance for the above-mentioned factors varied from 5 to 14 quanta. The fluctuation measurements were made by Hecht on 3 persons; he found that the number of photons sufficient to produce a visual effect varied from 5 to 7. It is obvious that the results he had obtained in the two cases were in good agreement.

Hecht's data come close to those obtained by the author for three observers, S. I.; P. G. and B. N., who showed a threshold varying from 3 to 14 quanta.

Thus, the quantity of energy necessary for visual effect runs into a score or two of quanta, while for persons of high sensitivity it does not exceed 3—4 quanta.

It will be apparent that under certain conditions the sensitivity of the human eye is near to the physical limit.

The author expresses his gratitude to S. I. Wawilow for valuable advice.

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REFERENCES

[1] E. Brumberg and S. Wawilow, Bull. Acad. Sci. URSS, série math., p. 919 (1933). [2] E. Brumberg and S. I. Wawilow, C. R. Acad. Sci. URSS, III, 1 (1934). [3] С. И. Вавилов, Труды Первой конференции по физиологич. оптике, Л., 1936, стр. 332. [4] S. I. Wawilow, Bull. Acad. Sci. URSS, série phys., No. 1—2, 176 (1936). [5] S. I. Wawilow, C. R. Acad. Sci. URSS, XXI, No. 8 (1938). [6] С. И. Вавилов, Глаз и солнце, 1941. [7] E. M. Brumberg, S. I. Wawilow and Z. M. Sverdlov, Journ. of Physics, VII, No. 1 (1943). [8] S. I. Wawilow and T. V. Timofeeva, ibid., VII, No. 1, p. 9—11 (1942). [9] S. I. Wawilow and T. V. Timofeeva, ibid., VII, No. 1, p. 12—17 (1943). [10] N. I. Pinegin, C. R. Acad. Sci. URSS, XXX, No. 3 (1941). [11] C. Roggenbau und A. Wetthauer, Klin. Monatsbl. Augenheilk., 79, 456 (1927). [12] E. Ludvigh and E. F. McCarthy, Arch. Ophthal., 20, 37 (1938). [13] S. Hecht, Journ. Opt. Soc. of America, 32, 1, 42 (1942).

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PHYSICAL CHEMISTRY

A METHOD OF DERIVING STATISTICAL RELATIONS IN THE FIELD OF SURFACE PHENOMENA AND ITS APPLICATION TO ADSORPTION PROBLEMS

By S. Z. ROGINSKY, Corresponding Member of the Academy

In modern theory of surface phenomena one of the central problems is to find out the relations that arise from the simultaneous presence on the surface of areas with different properties. In those cases where these areas give with respect to a certain primary parameter a continuous and sufficiently broad range («spectrum») of values, the typical problem reduces to the derivation of certain relations between directly observed quantities and the distribution function of areas with respect to primary parameters, and the reciprocal problem of finding the distribution function for the primary quantity on the basis of experimental relations discovered for secondary quantities.

For many surface phenomena it is convenient to choose the energy of sorption and the energy of activation for definite patches as the basic primary quantities. With these quantities a number of secondary characteristics of a patch are connected exponentially, which makes it possible to solve very simply many problems, and, in particular, the problem of sorption equilibrium on a complex surface(1).

Let us consider a complex surface with a distribution function with respect to the heats of sorption $\rho = dn/dQ$ characterized by a certain curve (see figure, *a*)

$$\rho = \frac{dn}{dQ} = \rho(Q) = \rho_Q \qquad (1)$$

The higher the value of Q for a given patch, the greater the increase of concentration

$$C_s = C_v e^{+F/RT} = C_v e^{-S/R} \cdot e^{+Q/RT} = C_v \beta e^{+Q/RT}$$

where C_s is the surface concentration of the sorbate and C_v is its concentration in the volume; F, S and Q are the differences between the free energy, entropy and heat content for a molecule absorbed by the surface of a definite patch, and the respective quantities for a free molecule of the sorbate, referred to one mol; and R is the gas constant.

With an increase in Q the average life-time $\bar{\tau}$ of a molecule on the surface increases

$$\bar{\tau} = \tau_0 \exp(Q/RT) \qquad (2)$$

Therefore in all cases where $Q_{max} \gg RT$ and $Q_{max} - Q_{min} \gg RT$, there exists for patches with different Q a broad range of pressures (concentrations), at which there are simultaneously present on the surface patches with a surface covering θ close to unity, and patches with a surface covering close

to zero. The first occupy a certain part of the total distribution $n = \int_{Q_{min}}^{Q_{max}} \rho_Q dQ$ on the right, and the second, on the left (see figure, *b*). The shape of the boundary separating these two parts depends upon the form of the function ρ_Q.

As a rule, the boundary is steep, forming a transition region with a width of the order of $4RT$. The boundary is S-shaped and nearly symmetrical. With an increase in p (or, correspondingly, in C_v), the boundary shifts to the left; moreover, the quantity of adsorbate increases by the size of the area $\Delta\pi$ (separated by the two border curves *I* and *II*) multiplied by the conversion factor γ.

It may be assumed that in the graph $\theta = \theta_1(Q)$ (see figure, *b*), *i. e.* without allowance for the distorting action of ρ_Q, the shape of the boundary curve does not change and the latter is translated parallel to itself. Therefore when ρ_Q is constant, the area $\Delta\pi$ may be replaced by the areas bounded on the sides by two verticals drawn through any two points of the boundary curves with identical θ, below by the axis of abscissae and above by a segment of the curve ρ_Q.

The same solution remains a good approximation until the ratio of the final change in ρ_Q over a width of the transition region ΔQ (*a* in figure) to the quantity ρ_Q itself, *i. e.*

$$\frac{\Delta\rho_Q}{\rho_Q} = \Delta Q \frac{d \ln \rho}{dQ} \tag{3}$$

is noticeably less than 1; then

$$dq = \gamma \int_{Q_{p_2}}^{Q_{p_1}} \rho_Q dQ \tag{4}$$

and the isotherm as a whole

$$q = \gamma \int_{Q_p}^{Q_{max}} \rho_Q dQ \tag{4a}$$

Making use of Langmuir's isotherm:

$$\theta = \frac{1}{1+\frac{b}{p}} = \frac{1}{1+\frac{b_0}{p}e^{-Q/RT}} = [1+e^{(-Q/RT)+\ln(b_0/p)}]^{-1} = [1+e^{-\alpha+\beta}]^{-1} \tag{5}$$

and choosing as constant for θ at different p's a surface covering $\theta = 0.5$, corresponding to equality of the quantities α and β or graphically corresponding to the point of inflexion on the boundary curve, we may replace Q_{max} by $-RT \ln(p_{min}/b_0)$ and Q_p by $-RT \ln(p/b_0)$. This substitution makes it possible to pass from $q = q(\rho_Q)$ to $q = q(p)$, *i. e.* to the adsorption isotherm.

Application of this method to the simplest forms of distribution gives for the isotherm:

1. $\rho = H(Q_{max} - Q)^n$.

$$q = \gamma H \int_{Q}^{Q_{max}} (Q_{max} - Q)^n dQ = - \left| \begin{array}{l} Q_{max} = -RT \ln(p_{min}/b_0) \\ \frac{\gamma H}{n+1}(Q_{max} - Q)^{n+1} = \\ Q = -RT \ln(p/b_0) \end{array} \right.$$

$$= \frac{\gamma H}{n+1}(Q_{max} - Q)^{n+1}$$

or

$$\sqrt[n+1]{q} = \sqrt[n+1]{\frac{\gamma H}{n+1}}(Q_{max} - Q) = \sqrt[n+1]{\frac{\gamma H}{n+1}}\left(RT \ln \frac{p}{b_0} - RT \ln \frac{p_{min}}{b_0}\right) \tag{6}$$

or, when $p \gg p_{min}$,

$$\sqrt[n+1]{q} \cong a \ln p, \tag{6a}$$

which is equivalent to

$$\ln q \cong (n+1) \ln \ln p + K \tag{6b}$$

with a particular solution when $n=0$, *i. e.* when $\rho = H$,

$$q \cong a \ln p \tag{7}$$

where $a = \gamma HRT$.

Of special interest for catalysis and activated sorption are the values $n=1$ and $n=-1/2$. They give

$$\sqrt{q} \cong a \ln p \tag{8a}$$

and

$$q^2 \cong a \ln p. \tag{8b}$$

Of these three particular isotherms the first is known and was studied by Frumkin and Temkin (2); the second and third isotherms are new.

II. $\rho = He^{-\alpha Q}$.

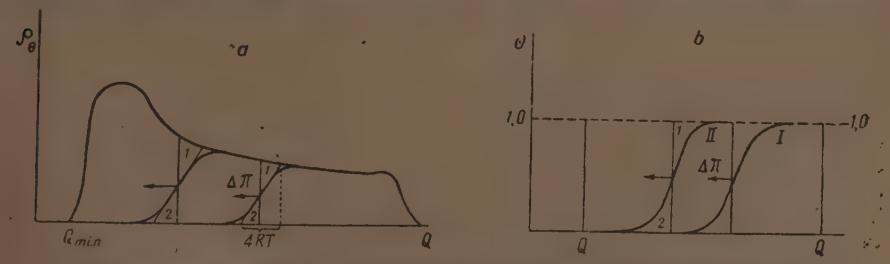
In this case the necessary condition for the applicability of the method is the inequality $\alpha RT < 1$. When $\alpha = 0$, II passes into $\rho = H$. Integration and the indicated substitution give

$$q = \frac{\gamma H}{\alpha} p^{\alpha RT} - \frac{\gamma H}{\alpha} p_{min}^{\alpha RT} = a p^{1/n} - a p_{min}^{1/n} \tag{9}$$

or, when $p \gg p_{min}$,

$$q \cong a p^{1/n} \tag{9a}$$

This is the Freundlich isotherm. Its statistical interpretation is not new (3), although not generally adopted. New for all cases is the general method of



Successive covering of the sorbent upon raising the external pressure

derivation, which is characterized furthermore l y exceptional simplicity. This method gives a sufficiently exact shape of the isotherm for the entire isotherm (except the very beginning and the very end), but an inaccuracy remains in the absolute value of q and, correspondingly, Q, due to the fact that the upper and lower areas *1* and *2* in figure *a*, *b* are not exactly equal. The error in Q cannot be greater than $2RT$. The areas would be exactly equal when the boundary curve is replaced l y a tangent to it at the point of inflexion and when ρ_Q is constant.

In the statistical theory of complex surfaces especially difficult is the inverse problem of finding the distribution from the isotherm. In our theory it becomes extremely simple and, as is clear from the derivation, reduces to a simple differentiation of the adsorbate with respect to dQ with opposite sign, which is easily converted to one of the following two forms:

from $\rho_Q = -dq/dQ = (-dq\,dp)\cdot(dp/dQ)$ we get:

$$\rho_Q = (p/RT)(dq/dp) \tag{10}$$

or, directly from $\rho_Q = -dq/dQ = -dq/d[-RT\ln p]$

$$\rho_Q = \frac{dq}{RTd\ln p} \tag{10a}$$

Application of this to any convex isotherm immediately gives the result sought. We will demonstrate this for the Freundlich isotherm:

$$q = ap^{1/n};\ \rho_Q = \frac{ap}{RT}\frac{d}{dp}[p^{1/n}] = \frac{a}{nRT}pp^{1/n-1} = \frac{a}{nRT}p^{1/n}$$

which by substitution

$$p = b_0\exp(-Q/RT)$$

gives

$$\rho_Q = \frac{ab_0^{1/n}}{nRT}e^{-Q/nRT} = \frac{H'}{RT}e^{-\alpha Q}$$

or

$$\rho_Q = He^{-\alpha Q}$$

where $\alpha = 1/nRT$.

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REFERENCES

[1] S. Z. Roginsky, Bull. Acad. Sci. URSS, sér. chim. (1944). [2] М. И. Темкин, Журн. физ. хим., 15, 296 (1941). [3] J. B. Zeldovich, Acta physicochimica, 1, 961, 1935).

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GEOCHEMISTRY

IODINE AND BROMINE IN THE BRINE OF MINERAL LAKES, IN NATURAL BRINES AND IN OIL WATERS

By A. I. DZENS-LITOVSKY

(Communicated by F. P. Savarensky, Member of the Academy, 29. II. 1944)

1. The brine and salt of the near-sea and continental mineral lakes contain small and minute quantities of a great variety of chemical elements supplied to the lakes in the form of different compounds, colloidal solutions, suspensions, dust, aerosols, *etc.* Hence in the brine of mineral lakes and in their clastic and chemical sediments, as well as in salt deposits and in natural brines of fossil salts, the greater part of the known elements may be revealed as small admixtures.

2. The elements of salts, brine and waters shed revealing light upon the possible geochemical composition of the contents of the water-reservoir. Thus, the high potassium and bromine content in the waters of the near-Kama area enabled N. S. Kurnakov, Member of the Academy, to predict the discovery of potassium salts in the Solikamsk region; the high potassium content of the Inder brine led to a discovery of borates and potassium salts in the region of the lake, *etc.*

Until now the brine of mineral lakes and natural brines have been but little studied with regard to their content of elements. The brine of mineral lakes, brines, and salt deposits have been studied in some detail only in so far as iodine and bromine are concerned.

3. Under natural conditions iodine and bromine occur in sea water, in the brine of lakes of various composition and origin, in mineral springs, natural brines, and oil waters. In addition, bromine in the form of isomorphous admixtures occurs in the fossil deposits of potassium and magnesium salts, and of rock salt.

In the carnallite rock of the Verkhnekamsk deposit of potassium-magnesium salts, bromine salts are contained in an amount of about 0.25—0.30 per cent (with regard to the mineral carnallite). Rock salt generally contains 0.001—0.004 per cent of bromine. It is therefore quite easy to understand the presence of bromine in the brines of salt deposits of fossil salts and in the brine of mineral lakes of a near-sea and continental origin. In natural brines of salt deposits and in the brine of mineral lakes no iodine is encountered, as a rule. Only in oil waters iodine is the usual associate of bromine (*).

4. The brine of mineral lakes may contain a large quantity of bromine —from 300 to 900 mg per litre, and sometimes even more. As shown by the investigations of the recent years, a particularly high bromine content is observed in the brine of mineral lakes, which are fed by natural brines of salt deposits of fossil salts, where the bromine is leached out together with the other salts from salt deposits. The brine of the same lakes does not contain any iodine or, at best, only traces of it.

5. Only the brine of all the mound mineral lakes and lakes, the feeding of which is connected with oil waters; is distinguished by a higher iodine content.

Upon the development of the petroleum industry at the Apsheron peninsula the chief rôle in the feeding of most of the mineral lakes of the peninsula passed to oil drill waters discharged to the lake hollows. All of these lakes contain in their brine a certain amount of iodine. In the brine of these mineral lakes

sulphates and salts of alkaline-earth metals are absent. The chief component of the salts contained in their brine are sodium chloride and bicarbonate. A characteristic component of the brine of these lakes is sodium iodide, the percentage of which is about 0.003.

6. Until now the presence of iodine has never been recorded in the brine and self-settling salt of the mineral lakes of the near-sea and continental type. Therefore it is quite recently that the question has been advanced whether iodine is really absent in the brine of mineral lakes, or the methods for iodine determination are not sensitive enough for revealing an insignificant content of it.

7. The studies of the physical-chemical properties of iodine and its various combinations carried out by A. P. Vinogradov, Corresponding Member of the Academy, shed light upon the startling absence of iodine in the brine of mineral lakes, in natural brines and salt deposits of fossil salts (1).

The geochemistry and the ways of iodine migration are of a different nature than that of the geochemistry of bromine. The dissemination of iodine and the ways of its concentration are also different from those of bromine.

In sea silt deposits iodine attains an exceptional concentration. All the silts of seas concentrate iodine in very considerable amounts and contain a quantity of iodine several thousand times that contained in sea water. Particularly rich in iodine are the silts of sea lagoons. Only its associate, the bromine, remains in the salt brines, which precipitates together with the salts.

That is why the waters of oil deposits are usually rich in iodine; these waters usually represent the «squeezed-out» water of sea silts, the «silt water» (1).

8. The accumulation of iodine in silts is caused by organic substances. Silts rich in organic matter are generally the richest in iodine.

The amount of iodine in the silts depends directly on the quantity of the fine fraction (less than 0.01 mm) contained in them. The fine fractions of silts; as suggested by Vinogradov; do not only contribute to the recovery of the iodine from the medium—sorption of iodine from the water, but also facilitate the fixing of iodine in silts of this kind, prevent it from being washed off (1).

9. The intersaline waters of fossil salts usually have a higher bromine content, iodine being completely absent. This is the «squeezed-out» intercrystalline bottom brine of those lake-lagoonal salt deposits from which salt deposits were formed in the process of diagenesis. The subsalt waters, and sometimes also the lateral waters of the deposits of fossil salts; contain both iodine and bromine.

The origin of iodine in the subsalt and near-salt waters of salt deposits is accounted for by the leaching-out of iodine compounds from ancient lake-lagoonal silts of the salt deposit; this is the «squeezed-out» bottom silt brine of the ancient lagoonal-lacustrine silt deposits in the process of diagenesis.

10. Our investigations carried on during many years on the natural brines of the Iletzk salt dome have shown that the salt brines and the brine of the lakes of the salt dome have an increased bromine content, iodine being absent in them. It was only in the course of preliminary prospecting drilling in the southern mining area that one drill-hole threw out an ancient mother lye (Urlaugen) with silt particles and an increased iodine content. It appears that the iodine content in this particular case is accounted for by the salt tectonics: during the dome formation, along with the salt the silt deposits of the lagoon were entrained and crumpled; from these the salt brine with iodine was «squeezed out».

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REFERENCES

[1] А. П. Виноградов, Тр. Биогеохим. лабор. Акад. Наук СССР, V (1939). [2] А. И. Дзенс-Литовский, Тр. Центр. научно-исслед. соляной лабор., 4 (1940). [3] А. И. Дзенс-Литовский, Бюл. Инст. галургии, № 6—7 (1940). [4] А. А. Иванов. Калий, № 5—6 (1934). [5] Ю. В. Морочевский. Тр. ВИГ'а, XVII (1939). [6] В. А. Сулин, Сборн. Результ. исслед. грязевых вулк. Крымско-Кавказской геологпров., М.—Л., 1939. [7] Г. Г. Уразов, Сборн. К исследов. озер юга России, Петроград, 1919. [8] E. Fulda, ZS. f. prakt. Geologie, I (1939).

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CHEMICAL TECHNOLOGY

THE CHLORINATION OF GARNIERITE

By D. P. BOGATSKY

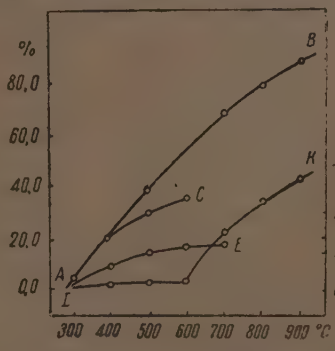
(Communicated by I. I. Černjaev, Member of the Academy, 17. III. 1944)

This paper is concerned with a research on the chlorination of garnierite, a hitherto unstudied process. The specimen studied came from the Tyulenev deposit in the district of Ufaley, the Urals, and was kindly supplied us by the Mineralogical Museum of the Academy of Sciences of the USSR.

An average sample had the following chemical compositon: Ni, 21.8 per cent; MgO, 12.34; CaO, 0.54; SiO_2; 37.02; lost on calcination; 17.8 per cent.

A sample of the mineral (about 5 g) ground down to 65 mesh was weighed out in a porcelain boat. The latter was then placed into a tubular furnace through which dry chlorine gas was passed at a constant rate (3 liters/hour). After treatment with chlorine for a definite period of time at various temperatures measured with a calibrated thermocouple, the sample was subjected to chemica l analysis.

To study the influence of preliminary reduction of garnierite upon the degree of chlorination; a series of chlorination experiments was likewise carried out with garnierite preliminarily reduced by hydrogen, illuminating gas, charcoal and anthracite. The results obtained are presented graphically in the figure.



The process of chlorination of garnierite as dependent on temperature. *AB*, degree of chlorination of garnierite and nickel extraction; *AC*, formation of non-volatile chloride of nickel, which is to be leached out; *DE*, dehydration of garnierite; *DK*, loss of weight in the course of chlorination

As follows from the experimental data obtained; the nickel from the investigated sample without reduction may be extracted completely under the experimental conditions only at temperatures not below 1100—1150°. However; the practical realization of the process of the chlorination of garnierite ores at such high temperatures in industrial conditions is fraught with great difficulties owing to the insufficient stability of refractory materials toward chlorine at these temperatures.

The method of direct reduction of oxidized and siliceous oxidized nickel ores that was proposed and for the first time proved to be an effective one [1] on application to the investigated samples considerably increased extraction of nickel during chlorination and provided the possibility of lowering the temperature of the process without increasing the reaction time. Thus, by chlorinating the investigated sample at 900°C over a period of 3 hours after reduction with hydrogen; 92.3 per cent of the initial amount of nickel it contained was recovered.

A still higher recovery of nickel was obtained in the chlorination experiments under the same conditions combined with direct reduction of garnierite by solid

carbon. Thus, the degree of chlorination of garnierite in a mixture with 10 per cent of anthracite slack rose to 94.7 per cent, while in a mixture with 10 per cent charcoal, to 96.7 per cent.

Conclusions. 1. The temperature at which chlorination of garnierite begins under the conditions studied was found to be about 280—290° C.

2. Upon increasing the temperature from 300 to 900°, the degree of chlorination of garnierite under the same conditions increases ftom 4.01 to 89.2 per cent; respectively.

3. Complete chlorination of garnierite in the experimental conditions may be achieved only in the temperature range 1100—1150° C.

4. Preliminary reduction of garnierite substantially increases its degree of chlorination and, consequently, considerably lowers the temperature for its complete chlorination.

5. The maximum degree of chlorination is obtained upon combining the chlorination processes with direct reduction.

6. The recovery of nickel from garnierite in these conditions has been increased to 96.7 per cent and may be increased still further.

7. Since the intensity of the chlorination process depends very slightly upon its nickel content, this method ensures practically complete recovery of nickel not only from poor but also from waste (inutilized) oxidized and siliceous nickel ores.

8. Moisture does not have a noticeable detrimental effect on the chlorination process; consequently, it is possible to apply the process of the chlorination of siliceous and oxidized nickel ores in practice without preliminary drying.

9. Nickel chloride forming during the chlorination process at temperatures up to 400° inclusive, remains entirely in the chlorinated garnierite.

10. Chlorination at higher temperatures is accompanied by the volatilization of the nickel chloride, which already at 600° reaches quite considerable proportions.

11. Chlorination (in the experimental conditions) at 800° is accompanied by the complete volatilization of all nickel chloride that has formed.

12. The experimental data on the chlorination of garnierite obtained in the present investigation make it possible to outline the fundamentals of the two following new flow-sheets for the processing of siliceous oxidized nickel ores by their direct reduction and treatment with chlorine gas:

a) reduction followed by chlorination in the temperature range 400—500° and subsequent leaching out with water of the nickel and other chlorides formed;

b) simultaneous reduction and chlorination at a temperature of the order of 800° followed by distillation and condensation of the nickel and other chlorides formed.

13. Cobalt also chlorinates readily under the conditions studied, which is of particular significance in the light of the great difficulties involved in modern methods of extracting it from siliceous oxidized nickel ores and the low yields obtained.

The author wishes to express his deep gratitude to Prof. G. G. Urazov, Corresponding Member of the Academy, and Prof. V. A. Vanyukov for their generous advice in the course of this work.

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REFERENCES

1. Д. П. Богатский, Сб. научн. трудов Моск. ун-та цветных металлов и золота, № 6 (1938).

Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
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GEOLOGY

RELATION BETWEEN SEDIMENTATION ZONES AND FOLDING ZONES OF THE WESTERN SLOPE OF THE URALS IN THE UPPER PALAEOZOIC

By V. D. NALIVKIN

(Communicated by W. A. Obruchev, Member of the Academy, 27. III. 1944)

The works of the recent years have shown that on the western slope of the Urals for the Artinskian stage, the Upper Carboniferous and partly the upper part of the Middle Carboniferous there exist several zones of sedimentation stretching along the Ural range. In the east an areno-conglomerate zone is developed, followed further west by an areno-argillaceous, further on by an argillo-carbonate and lastly by a carbonate zone. At the boundary of the argillo-carbonate and the carbonate zone reef massifs are intensively developed.

The oldest coarsely clastic facies are located in the east, the young ones, in the west. This migration may possibly be due to the shifting of the old Ural range from east to west.

The most distinct is the boundary between the argillo-carbonate and the limestone zone, for the epoch from the *Schwagerina* horizon to the lower portion of the horizon with *Pseudofusulina lutugini* Schell. In the greater part of time this boundary seems to have suffered scarcely any migration; it stands out distinctly for its lithological features, altered composition of its fauna, and its occurrence within the reef massifs. In addition, it is the best studied one, since for a long time it has been considered as a boundary between the Permian and the Carboniferous, which was the cause of dispute among the geologists; it is to this boundary that the oil deposits of the reef type are confined.

Legend. *1*, area of intense folding; *2*, development area of the limestone facies for the time from the *Schwagerina* horizon to the horizon with *P. lutugini*; *3*, development area of terrigenous deposits in the upper horizons with *P. lutugini*

In tracing the geographical position of this boundary (see figure), we shall see that in the south, in the region of Ishimbay, the boundary of the carbonate and the argillo-carbonate facies passes between the oil-bearing reef massifs and the «shikhans» in the east, and the villages of Allaguvatovo, Pokrovka and Kossyakovka, in the west.

East of the carbonate facies there are developed thin-bedded aphanitic clayey and organogenic-clastic limestones with a scarce fauna, about 200 m thick.

In the area of transition from the carbonate to the clayey-carbonate facies hydractinoid-bryozoan reef massifs are located, the thickness of which attains 1250 m.

North of Ishimbay the position of the boundary considered is determined by a gravitational step, marking the transition from the dolomitic facies of the Kungurian to the salt-bearing facies. The gravitational step first follows along the railway line Ufa—Ishimbay and then turns to the town of Asha.

North of the town of Asha the boundary of the carbonate and the clayey-carbonate zone is broken by the Kara-tau overthrust, beyond which it may distinctly be traced along the eastern margin of the Ufa plateau to the town of Krasnoufimsk.

The sections of the eastern margin of the Ufa plateau are very much like those of Ishimbay. Their lower part is composed by coralline-*Stafella*, algal and hydractinoid limestones, in the upper part silicified lit-par-lit. The apparent thickness is 350 m.

The upper part of the section is represented by laminated, slightly clayey, *Fusulina*-bryozoan limestones of the lower part of the horizon with *Pseudofusulina lutugini*. The thickness of the upper part in the south near the Kara-tau range equals 150 m; in the region of the Ai river, about 300 m, and in the Chernaya Rechka hole, 400 m.

Thus, the thickness of the horizon with *P. lutugini* is the least near the Kara-tau range, gradually increasing south and north of the latter. This fact points to that at the given epoch the area of the Kara-tau range was probably subject to a lesser subsidence than the areas lying to the north and south.

On the Ufa plateau, like in the Ishimbay region, a gradual increase in the variety and richness of the fauna is observed in a direction from west to east, resulting at last in the formation of hydractinoid-bryozoan reef massifs (towns of Yaroslavka, Tastuba, *etc.*).

East of the carbonate facies of the Ufa plateau at present only the uppermost portion of the clayey-carbonate facies is known. North of the town of Krasnoufimsk the easternmost point of development of the carbonate facies lies in the vicinity of the town of Chussovoy.

In comparing the sections of the Kizel basin, of Chussovskiye Gorodki and of Krasnokamsk, it may be seen that the richest and most diverse fauna is found in the east, in the Kizel basin, which is characteristic—as it has already been noted for the Ufa plateau and the region of Ishimbay—of the eastern boundary of development of the limestone facies.

The extensive development of hydractinoid reefs in these regions is also evidence in favour of the conclusion that the boundary between the carbonate and the clayey-carbonate facies actually passes directly east of the town of Chussovoy and of the Kizel basin.

Finally, the northernmost region where the boundary discussed is traceable is the Kolvo-Vishera district.

The presence of hydractinoid reefs; the development of terrigenous deposits around and within them in this region distinctly marks the eastern boundary of the development of the limestone zone of sedimentation.

As it has been shown above, the sedimentation zones are parallel to the old folded ranges, the carbonate zone lying far from them, and the coarsely-clastic facies at their foot.

What are then on the recent geological map of the Urals the mutual relations between the boundary of the carbonate and clayey-carbonate zone of sedimentation traced above and the folded zones?

In the south, in the Ishimbay region, they are nearly parallel to each other. Further north this boundary is crossed by the Kara-tau overthrust extending far into the area of development of the limestones. Beyond the overthrust it draws away from the area of strong folding, but near the town of Chussovoy it returns to that area and does not leave it until the Kolvo-Vishera district (see figure).

Consequently, the zones of sedimentation which existed at the epoch from the *Schwagerina* horizon to the lower portion of the horizon with *P. lutugini* Schell.

are crossed on the map by the boundary of a younger folding, extending further west.

This migration of folding has also been reflected in the type of sediments of the upper part of the horizon with *P. lutugini*.

In the southern regions where the carbonate facies of the underlying horizons lies outside the zone of intensive folding, the boundary of the carbonate and the clayey-carbonate facies approximately coincides with the same boundary for older deposits. North of the town of Krasnoufimsk upon approaching the Kizel basin, the former boundary deviates increasingly to the west, following the margin of the folded area. As pointed out above, in the Kizel basin the lower part of the horizon with *P. lutugini* Schell. is composed of limestones, while the terrigenous deposits of the upper part of this horizon reach much farther westward—to the region of the Upper Chussovskiye Gorodki. They have been exposed by a drill-hole near the town of Cherdyn (see figure).

Another fact which seems to be connected with the appearance of a young folding extending to the west, is the formation of the Kungur depression situated west of it. This depression is characterized by great thicknesses of Kungurian deposits — 500 to 900 m—and by salt deposits (Upper Chussovskiye Gorodki, Solikamsk; Cherdyn).

Conclusions. 1. On the western slope of the Urals, during the Upper Palaeozoic, the zones of sedimentation and of the display of intensive folding were non-uniformly shifting from east to west, along the Urals. In some areas (the Kizel basin) they extended to greater distances, while in others they were scarcely displaced if at all (the Ufa amphitheatre).

2. In the Urals there existed an intense phase of folding (in addition to the older ones), confined to the uppermost portion of the Artinskian stage and the lower part of the Kungurian.

3. Knowing the position of the eastern boundary of the limestone facies in the time interval discussed, and its relation to the areas of manifestation of intensive folding, important conclusions may be made concerning the distribution of the reef massifs confined to this boundary. This is of considerable practical importance, since the reef massifs are promising structures with regard to the presence of oil.

4. The oil-bearing reef massifs of the Ishimbay (and not the Chussovskoy) type should be looked for along the eastern border of the limestone facies, within the area between Ishimbay and the town of Asha, then along the eastern border of the Ufa plateau to the town of Krasnoufimsk and further north, between Krasnoufimsk and the town of Chussovoy, where the position of the zone of development of the reefs may be suggested only from an analysis of the extension of the eastern boundary of this facies.

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HISTOLOGY

INFLAMMATORY RESPONSE OF THE CONNECTIVE TISSUE IN THE *AMPHIOXUS*

By L. ZHINKIN

(Communicated by A. A. Zavarzin, Member of the Academy, 29. III. 1944)

In spite of the exceptional taxonomic position occupied by the *Amphioxus lanceolatus* and the numerous detailed studies concerned with it, many questions on the structure of this interesting representative of the lower *Chordata* remain inadequately investigated up to the present. Although the embryology and morphology of the *Amphioxus* have been studied in the greatest detail, the same cannot be said of its histological structure. According to the data reported by Cuénot (1), subsequently corroborated by other authors, the blood of the *Amphioxus* does not contain any cellular elements whatever. Metchnikoff (2) points to the failure of every attempt to provoke an inflammatory response in the *Amphioxus*. According to embryologists (3,4), the *Amphioxus* lacks rudimental mesenchyme. We see that the development and the characteristics of the connective tissue of the *Amphioxus* remain quite obscure.

In studying the regeneration of thoracal muscles in the *Amphioxus* I had the occasion to observe simultaneously the typical response of its connective tissue provoked by traumatization.

The experiments were done at the Sevastopol Biological Station of the Academy of Sciences of the USSR in summer 1938.

We were investigating the ability of the muscles and at the same time that of the connective tissue to regenerate, and for this purpose we arranged the following experiments: a subcutaneous wound was made in the side of an *Amphioxus* approximately in the middle of its body, nearer its dorsal surface, by means of a fine sharp scalpel. Occasionally a fine needle was introduced under the skin instead of the scalpel. The end of the needle was bent a little, so as to destroy several myocommae and the muscles lying between them in the act of extracting it.

Notwithstanding the brevity of these experiments, the period of observation being only 12 days, we were able to obtain a very distinct inflammatory response in the connective tissue. Immediately after the traumatization speedily developing destructive processes begin in the body of the *Amphioxus*, namely in the myocommae and muscles; they expand to the area surrounding the traumatized region. Simultaneously with this process of destruction active cells of the connective tissue make their appearance. Because of their mobility and phagocytic capacity, these cells may provisionally be given the name of amoebocytes. These amoebocytes are formed from the small connective tissue cells, sparsely scattered within the essential substance of the myocommae or around it. This process is still more demonstrative in the epithelioid layer of cells lying in the internal side under the corium of the skin, which Joseph (5) named the endothelium. There is no special difference between the transformation of the «endothelial» cells and that of the cells of the myocommae; therefore the transformation of both into amoebocytes may be described together. The nuclei of the cells begin to enlarge and to assume

a round form, the quantity of protoplasm also increases and the latter becomes more basophilic. A large cell with an oval nucleus, lying excentrically as a rule, is formed as the result of this transformation. Its nucleus is clear and large and possesses a large caryosome, the protoplasm is basophilic and to some extent vacuolized; the size of the vacuoles varying greatly (Fig. 1). These cells round up, lose their former tissue connexions and proceed to a free existence, passing into the cavity of the defect. Cells of this type we feel justified to name, by way of analogy with other animals, amoebocytes. The formation of amoebocytes takes place not only at the site of the defect, but at some distance from it also. The amoebocytes thus formed are actively mobile and begin to multiply caryokinetically from the moment of their formation. The mitotic activity of the newly formed cells is very intensive.

Fig. 1. Beginning of the formation of amoebocytes. 5 days after operation. *e*, «endothelium»; *b*, corium; *a*, formed amoebocyte

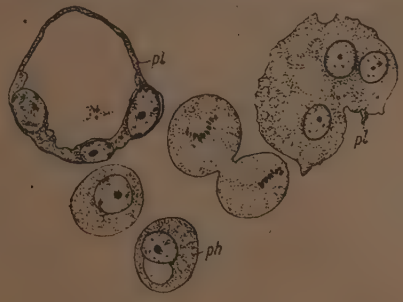

Fig. 2. Accumulation of phagocytes. *pl*, plasmocyte; *ph*, phagocyte

The amoebocytes accumulate at the site of the defect and begin to phagocyte the scraps of tissue and the disintegrating muscle, clearing the cavity of the defect. This phagocytosis is performed both by isolated amoebocytes and by their groups, forming polynuclear plasmodia. Such plasmodia form usually around larger necrotized particles, the protoplasm of the plasmodium surrounding in a thin layer the particle which is being phagocyted (Fig. 2).

The phagocyting cells cease multiplying, but the arriving fresh amoebocytes divide continuously; therefore one always finds dividing amoebocytes amid charged phagocytes. Charged phagocytes and plasmodia formed by them come gradually out of the cavity of the defect. Our attempts to find pictures showing the death of charged amoebocytes have been fruitless. The response to traumatization occurs in connective tissue from the very first days and takes its course at such a rate that by the seventh day the cavity of the defect begins to clear itself of phagocytes. Simultaneously with the disappearance of phagocytes the amoebocytes begin to undergo new changes. These changes take place both in those amoebocytes which were already present during phagocytosis, though not taking part in it, and in those forming later. The formerly rounded cells assume an irregular shape, they become oblong, are supplied with protuberances, their protoplasm becomes more homogeneous (Fig. 3). Their aspect reminds of desmoblasts. The multiplication of such desmoblasts continues with the same intensity, and in every microscopic field of vision one always finds cells in the act of division. Later on these desmoblasts with protuberances, which have formed from amoebocytes, fuse by their protoplasmatic protuberances into a desmoblastic syncytium. The cells of such a syncytium are loosely bound and their multiplication stops entirely. We were unable to observe in what manner the syncytium is formed. It may possibly be formed by cell fusion, since we never met any amitotic forms with an incomplete cell plasmotomy. The stain used (azure-eosin) did not allow to follow up the initiation of the essential substance, but the general appearance of the desmoblastic syncytium and the character of the cell protoplasm seem to indicate that this initiation begins already by this time (Fig. 4). The formation of such a syncytium occurs

approximately on the 12th day from the beginning of the experiment; and the data collected by us end here.

Notwithstanding the shortness of the time of observation, the data collected show with sufficient distinctness the existence of an inflammatory response in the connective tissue of *Amphioxus lanceolatus*. Typical amoebocytes, capable of phagocytosis and able to transform into desmoblasts, are formed after traumatization out of the cells of the epithelial layer and from those lying in the myocommae.

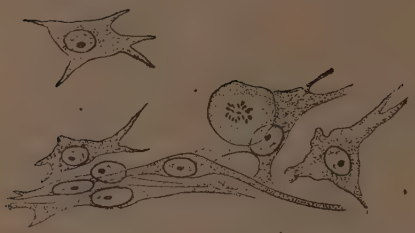

Fig. 3. Beginning of the formation of desmoblasts. 7 days after operation

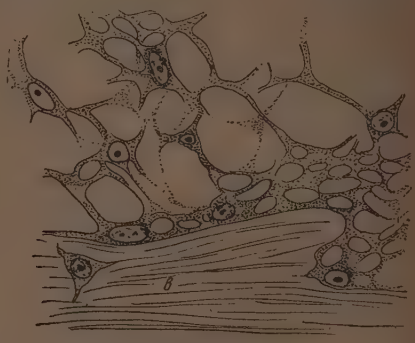

Fig. 4. Desmoblastic syntycium. 12 days upon operation

The ability to form cells taking part in the inflammation belongs to the derivatives of the dermatome and sclerotome. The derivatives of the myotome are used up in their totality for the formation of muscle tissue and in case of regeneration form only muscles. Accordingly, only one kind of cell elements capable of phagocytosis and desmoblastic transformation is formed in the connective tissue of *Amphioxus lanceolatus* after irritation. Its formation occurs by way of histiogenesis; characteristic of vertebrates. At the same time we must consider the formation of only one kind of connective tissue cell as a primitive character. All these specific characteristics of the structure and of the inflammatory response of the internal medium must be regarded as the result of an extreme specialization and of a secondary simplification of the histological structure of *Amphioxus lanceolatus*.

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REFERENCES

[1] L. Cuénot, Arch. de zool. exp. et gén., 2 série, IX, 13 (1891). [2] П. П. Мечников, Лекции по сравнительной патологии воспаления, 1917. [3] E. Conklin, Journ. of Morph., 54 (1932). [4] П. П. Иванов, Общая и сравнительная эмбриология, 1937. [5] Joseph, Arb. Zool. Inst. Wien, 13 (1901).

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GENETICS

LOGARITHMIC RECTIFYING OF PARABOLIC REGRESSION LINES OF ANIMAL CHARACTERS AND INTRASPECIFIC VARIATION

By W. W. ALPATOV

(Communicated by I. I. Schmalhausen, Member of the Academy, 23. II. 1944)

Within the two recent decades the function

$$y = bx^k \qquad (1)$$

has widely been used by zoologists; certain writers (7) have successfully applied this function in order to correlate variations taking place in separate parts of the organism with variations in the organism as a whole. Others (14) have suggested it for the description of the variation of characters with time. A distinctive feature of the parabolic function consists in that when finding logarithms of absolute values of the variables; this function is being transformed into a linear relation, since, upon logarithmizing, equation (1) assumes the form $\log y = \log b + k \log x$. This makes it possible to pass to regression lines, the calculation of which is a rather simple procedure, and which go well to characterize the changes of logarithms of a definite character after the logarithms of another.

The parabolic functions and their anamorphoses did not fail to attract the interest of taxonomists. Thus, Huxley (7) wrote in 1932: «systematists are agreed that mere size differences may have no taxonomic significance, since they are often the direct effects of environmental changes. But they usually attach much greater importance to differences in the percentage size of parts. Our studies in heterogeny; however, make it obvious that such differences may have precisely as little taxonomic significance as those in absolute size, for wherever an organ is heterogenic, differences in absolute total size of body will bring about differences in relative size of the part».

Monastyrsky (13) has shown that in the case of double logarithmic diagram the parabolic relation between body length in a fish and the size of its scales is transformed into a linear one.

Tyurin (18) applied double logarithmizing to the analysis of body length and weight in fish. Nomura (19) made use of the parabolic formula for finding out the relation between the dimensions of shells in molluscs. This author has pointed out the variation of the constants of curves brought about by different environmental conditions of molluscs within the same species. During the recent years double logarithmizing has been applied to the study of allometry in fish and mammals (1, 3, 4).

No attention has until now been attached to phenomena of intraspecific variation, *viz.* to the comparison of subspecies and races by regression curves of their absolute characters and indices of the latter.

If a taxonomist has to do with groups of such animals as go on growing after having attained sex maturity, the biometrical description of the body characters of these animals connected with the study of intraspecific forms proves a rather complicate affair. Endeavours have been made to make use of indices instead of absolute characters. But it was shown by Johannsen (8) on anthropological material, and by Goodwill (5) on fish that those attempts are lacking any solid

foundation: since indices are subject to considerable variation along with the absolute dimensions of the respective characters. It is a matter for regret that ichthyologists persist in their fallacy and continue to calculate indices and their mean error without making any allowance for the absolute dimensions of the animal groups compared (*).

Three types of parabolic correlations of characters are thinkable, x, y and z.

1) Correlations between the absolute values of the characters: x and y; x and z; y and z.

2) Correlations between the index and one of the characters comprised in the index: x/y 100 and y.

3) Correlations between the index and a character not comprised in the index: x/y 100 and z.

A complete picture of the variations of a character or index analysed as dependent on some changes occurring in another character or index cannot possibly be obtained unless we find: 1) the coefficients of regression with their mean or probable errors, and 2) the equation of straight line regression, with the aid of which it is possible to find any values of the character investigated, connected with the variations in the absolute dimensions of another character. In the latter case it is necessary to find out the mean or the probable error in the value of the character or index calculated from the regression equation.

The following formulae have been made use of.

Regression coefficient of the character y from x:

$$b_{y/x} = r_{yx} \frac{\sigma_y}{\sigma_x} \qquad (2)$$

Probable error of the regression coefficient:

$$PE = 0.6745 \frac{\sigma_y}{\sigma_x} \sqrt{\frac{1 - r_{yx}^2}{N}} \qquad (3)$$

Equation of regression:

$$y = b_{y/x}(x - Mx) - My. \qquad (4)$$

where r is the correlation coefficient; Mx and My, the arithmetical means; N, number of cases; σ_y and σ_x, standard deviations of the character studied.

The probable error involved in the value of character y, calculated according to the regression equation, for a definite value of the character is as follows (**):

$$PEy = 0.6745 \sigma_y \sqrt{\frac{1 - r_{yx}^2}{N}} \sqrt{1 - \left(\frac{x - Mx}{\sigma_x}\right)^2}$$

It is better to take $N = 2$ (*).

This formula holds for the case of a random selection of a volume N out of considerable wider population, on the assumption that N specimens are taken without any reference to one another, like the balls are removed from the ballot-box.

An instance of constants calculated for the former type of correlations will be found in Tables 1 and 2, plotted on the basis of correlation data for logarithms of body height and body length in three forms of *Rutilus rutilus* L. Only *R. r.caspicus* shows a regression coefficient different from that of *R. r. typicus* ($R = 3.8$). 95 chances against 1 are thus in favour of the conclusion that such a difference is not due to random sampling.

By the logarithm of body height, calculated for a logarithm of a body equal to 2.2, the differences between all the three forms are statistically significant. For the correlation of the second type I made use of the same original data referring to *R. rutilus* L. (Tables 3 and 4). In the main the picture obtained permits of conclusions similar to those derived from an analysis of the correlations of the first type.

Table 1

Regression Coefficients $b\frac{\log y}{\log x}$, their Errors and Relations between Differences and their Errors (R) in Three Forms of *Rutilus rutilus*: *typicus*, $N=54$; *fluviatilis*, $N=74$; *caspicus*, $N=86$
(Measurements by Pravdin. 1915: y, body height; x, body length)

		b	1	2	3
Rutilus r. typicus . . .	1	0.912 ± 0.0445	0	$R=2.39$	$R=3.78$
R. r. fluviatilis . . .	2	1.085 ± 0.0564	0.1730 ± 0.723	0	$R=0.29$
R. r. caspicus	3	1.097 ± 0.0179	0.185 ± 0.0490	0.0120 ± 0.0416	0

Table 2

Logarithms of Body Heights Calculated According to Equations $\log y = b_{y/x}(\log x - \log Mx) = \log My$ with Corresponding Probable Errors, Differences and Relations between Differences and Errors for Different Forms of *R. rutilus*

		$\log y$	1	2	3
Rutilus r. typicus . . .	1	1.657 ± 0.0046	0	$R=8.9$	$R=4.29$
R. r. fluviatilis . . .	2	1.7060 ± 0.0030	0.0490 ± 0.0035	0	$R=6.82$
R. r. caspicus	3	1.6780 ± 0.0028	0.0210 ± 0.0049	0.0280 ± 0.0041	0

It is of interest to note that the ratio serving to evaluate the differences between the calculated indices for a length equal to 2.2 proves to be considerably higher than those obtained when evaluating absolute values (Tables 2 and 4). Hence it should be inferred that in the case where the correlation of absolute values fails to give the necessary answer, recourse should be had to the correlation between the index and one of the values it comprises.

Table 3

Regression Coefficients $b\frac{\log t}{\log x}$, their Errors and Relations between Differences and Errors (R) in Three Forms of *R. rutilus* (i, index of body height; x, body length)

		b	1	2	3
Rutilus r. typicus . . .	1	0.1681 ± 0.0183	0	$R=2.89$	$R=3.1$
R. r. fluviatilis . . .	2	0.0763 ± 0.0268	0.0918 ± 0.0318	0	$R=0.89$
R. r. caspicus	3	0.1016 ± 0.0113	0.0664 ± 0.0215	0.0253 ± 0.0283	0

Table 4

Logarithms of Indices of Body Height Calculated According to Regression with Corresponding Probable Errors, Differences and Relations between Differences and Errors for Different Forms of *Rutilus rutilus*

		$\log t$	1	2	3
Rutilus r. typicus . . .	1	1.4544 ± 0.0021	0	$R=28.7$	$R=7.8$
R. r. fluviatilis . . .	2	1.525 ± 0.0009	0.0661 ± 0.0023	0	$R=24.4$
R. r. caspicus	3	1.4761 ± 0.0018	0.0217 ± 0.0028	0.0489 ± 0.0020	0

Finally, let us take as an example of the third type correlation the correlation between the proportions of the chelae and the length of the carapace in a fresh-water crayfish. Birschtein and Winogradow (2) have made an attempt to subdivide the species *Astacus leptodactylus* Eschh. into five subspecies; three of these have been described by the writers cited above in a rather laconic manner; without

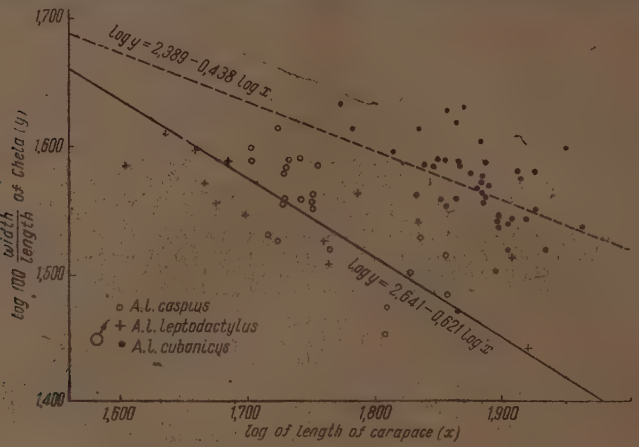

Fig. 1. The correlation between the index of the length of the chela and that of the carapace as expressed in their respective logarithms for subspecies of *A. leptodactylus* Eschh. (males)

giving any numerical characteristics. The shape of the chelae has been given the foremost place in the diagnosis of the subspecies.

2) The following measurements have been made by myself: 1) length of the chela, maximum width of the chela and 3) length of the carapace. The material for

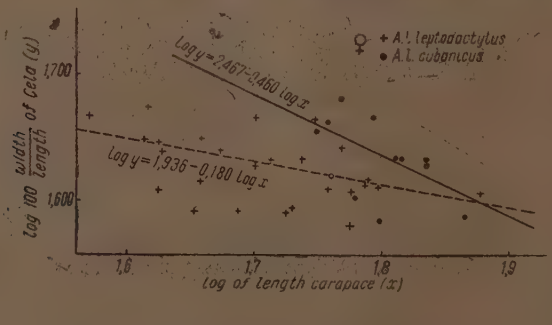

Fig. 2. Same as in Fig. 1, referring to females

these measurements has been obtained from the Zoological Museum of the Moscow State University: all the specimens were supplied with determinations by Birschtein and Winogradow. The origin of the specimens measured is the following: *A. leptodactylus leptodactylus* Eschh.; mostly from environs of Moscow; *A. l. cubanicus* Birsch. et Win. from the rivers Sal, Don and Kuban; *A. l. caspicus* Eich. from the Caspian sea. In Figs. 1 and 2 the logarithms of the width indices of the chelae are plotted against the logarithms of the length of the carapace. The empirical points have been found to fit in the straight lines whose constants have been found by the method of least squares (14).

From the distribution of the points and of the straight lines obtained it may be seen that the Kuban subspecies is characterized by a wider shape of the chelae as compared to the typical *A. l. leptodactylus* and to *A. l. caspicus*. This difference is especially conspicuous in males and still more so in males of large dimensions. In the females the picture is a reverse one; and the difference becomes as it were smoothed out in the largest specimens. The material at my disposal being a rather scanty one, I am unable to back my conclusions statistically, and it can therefore be no discussion of the significance of these differences. For this reason I withheld from calculating the errors of the constant and those of the calculated logarithms for the length of carapace of definite dimensions.

The method which I am suggesting for the study of intraspecific variation may be called the regression method of double-logarithmic absolute and relative characters. It can be applied on a wide range to the taxonomy of such groups of animals in which the growth of the body and of its separate parts proceeds during a large part of the ontogenesis. Among such forms are to be classed worms, crustaceans, molluscs, amphibians, reptiles and mammals, inclusive of man. It is likely to find application in botany, as well.

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Received
23. II. 1944.

REFERENCES

[1] B. Aoki and R. Tanaka, Mem. of the Fac. of Sci. and Agric. Taihoku Univ., XXIII, No. 1 (193...). [2] Н. Бирштейн и Л. Виноградов, Зоол. журн., XIII, No. 1 (1934). [3] P. Butler, Journ. of Mammal., 22, No. 1 (1941). [4] F. Clark, Fish. Bull. Divis of Fish and Game of Calif., No. 12 (1928). [5] С. Гудвин, Вестник рыбопромышл., No. 12 (1915). [6] Т. Лементьева и Г. Монастырский, Труды Бс. н.-и. ин-та морск. рыбн. хоз. и океаногр., X (1939). [7] J. Huxley, Problems of relative growth. London. 1932. [8] W. Johannsen, Arch. f. Rass. und Gesell. Biol., 4 (1907). [9] J. Miner, Ann. of Mathem. Statist., 2 (1931). [10] E. Nomura, Sci. Rep. Tohoku Imp. Univ., 4 ser., No. 2 (1927). [11] K. Pearson, Biometrica, 9 (1913). [12] Н. Правдин, Матер. к познан. русск. рыбол-ва, IV, 9 (1915). [13] Г. Монастырский, Сб. статей по методике определения возраста и роста рыб. Красноярск, 1926. [14] I. I. Schmalhausen, Roux Archiv, 109, 110 (1927); 125 (1930). [15] Н. Тюрин, Труды Сиб. ихт. лаб., II, 3 (1927)

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MICROBIOLOGY

PHYTOHORMONAL ACTIVITY OF SOIL BACTERIA

By N. A. KRASSILNIKOV

(Communicated by A. A. Richter, Member of the Academy, 28. II. 1944.)

The prevailing interpretation of the soil microflora as a factor responsible only for the biochemical transformations of substances in nature and in soil-forming processes, in particular, does not reflect the data which have accumulated within the last years.

There is sufficient ground at present to believe that soil microorganisms are, besides their other functions, a powerful growth factor for the plants.

Bacteria produce in the course of their life process growth substances, such as auxines, vitamins and their derivatives, aminoacids, such substances as pantothenic and nicotinic acids and other chemical compounds. Some authors find in bacteria largely growth substances of the auxine type ([1], [14], [15]), others ([11], [12], [16]), vitamins and their derivatives.

According to our observations, different bacterial species produce different growth substances in varying quantities. Bacterial strains of the *Pseudomonas* group are the richest in growth substances, after these comes the *Azotobacter*, the non-sporulating bacteria of the *Achromobacter* group, while these substances are almost entirely lacking in sporulating bacteria, mycobacteria and mycococci. Rasnitzina and Nakhimovskaya have found in *Pseudomonas* cultures much greater quantites of auxines and vitamin B_1 than in those of *Azotobacter*. Neither auxines nor vitamin B_1 are formed by nodule bacteria growing on synthetic media without triptophane, though pantothenic acid and riboflavin are present in such cultures. In cultures of other bacteria (*Achromobacter*, *Mycobacterium*) we do not find the compounds mentioned or find very small quantities of these. This does not mean that these bacteria do not form any growth substances whatever. It must be assumed that under certain conditions of growth every or almost every microbe species is able to form greater or smaller quantities of certain compounds necessary for its life activity.

The growth substances formed by bacteria produce the same effect on the higher plants as the pure chemical preparations of these. We grew several roots (0.5 cm long) of peas, maize and wheat in synthetic media with or without the products of bacterial metabolism (we experimented with *Azotobacter*, nodule bacteria, *Pseudomonas*, *etc.*).

As we know from the studies of Bonner ([6]), Robbins ([13]) and those of other authors, severed roots of plants need accessory factors for their growth. They can be grown indefinitely in mineral solutions containing sugar to which such substances as vitamins, pantothenic or nicotinic acids, certain aminoacids, β-alanine, thiazole, pyrimidine *etc.* have been added.

In our experiments we added to the media, instead of the compounds mentioned above, extracts or filtrates of bacterial cultures grown in synthetic media, and obtained the same effect. Pea roots (0.5—0.7 cm long) reached the length of 16 cm after 10 days of growth in the presence of *Pseudomonas fluorescens* metabolites (Table 1).

By transplanting the tips of a pea root (0.5 cm long) from flask to flask, we were able to keep up its growth for a period of 5 months. The total length of the roots with their lateral branches obtained during this period exceeded 6 m.

On the same substrate without bacterial products pea roots do not produce any growth. An insignificant growth is observed in the first passage only, probably at the expense of the growth substances which were present at the tip of the roots.

Maize and wheat roots grow most intensively in the presence of metabolites of *Pseudomonas aurantiaca* and of *Azotobacter vinelandii* (Fig. 1), while their addi-

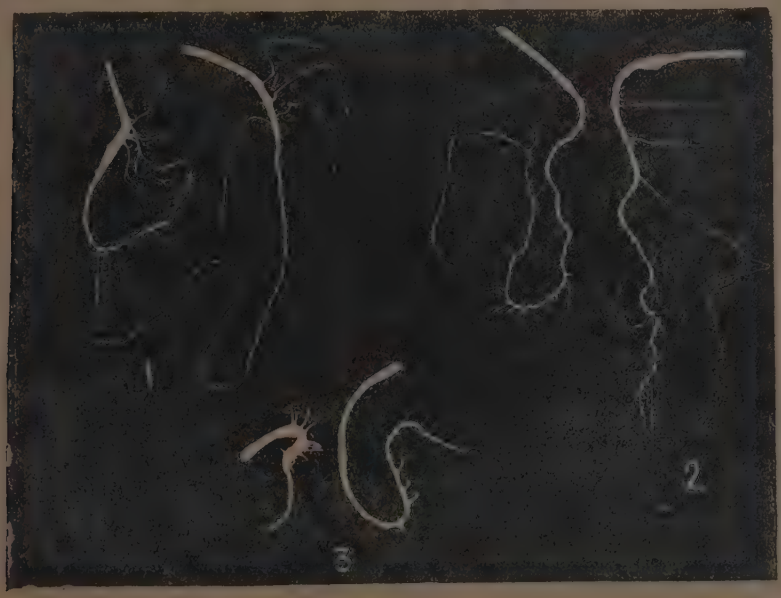

Fig. 1. Maize roots grown in a synthetic medium in the presence of bacterial metabolites: 1, *Pseudomonas fluorescens* (strain 36); 2, *P. aurantiaca* (strain 1); 3, control plants

tional growth obtained with the aid of *Pseudomonas fluorescens* was comparatively small.

Table 1

Growth of Isolated Roots in the Presence of Bacterial Metabolites

(Length of roots in cm. of the 2nd passage by the 10th day of growth)

Extracts of bacteria, added to the medium	Roots of		
	peas	maize	wheat
Control	0.7	0.5	0.5
Azotobacter chroococcum	5.0	10.0	6.0
» *vinelandii*	10.5	15.0	23.0
Pseudomonas fluorescens	16.5	9.5	5.5
» *aurantiaca*	4.3	21.5	12.8
Rh. meliloti	6.0	3.0	5.0
Rh. trifolii	8.0	2.0	4.0
Achromobacter	0.9	2.5	6.0

Nodule bacteria produced in our experiments but a slight effect on isolated roots, while most *Achromobacter* strains showed no effect on the growth of roots. Only one strain out of 10 produced a slight growth increase in wheat and maize roots.

Soil bacteria affect the rooting of cultures. A great number of experiments have been done lately on the hormonization of cuttings by means of various preparations of growth substances [2, 3, 4]. The results obtained are so important that this method is already being introduced into horticultural practice.

We observed the formation of roots by lemon cuttings. The latter were kept in a bacterial culture for 12—30 hours and then planted into sand. This bacterial treatment of the cuttings shortens the time necessary for the rooting by 2—6 days (Table 2).

Fig. 2. Effect of bacterial metabolites on the growth and rooting of pea scions: *1, Azotobacter chroococcum*; *2, Pseudomonas fluorescens* (strain 6); *3, P. aurantiaca*; *4, P. fluorescens* (strain 36)

Pea cuttings treated with cultures of nodule bacteria took root on the 5th day, while the controls did so only on the 10th day. The growth of treated branches used as cuttings was considerably increased (Fig. 2).

Potato branches without leaves, planted after treatment with *Pseudomonas* cultures into a soil-peat mixture, form tubers on the 7—8th day, the untreated controls —not until the 10—12th day. The controls produced 91 tubers per 100 cuttings, the treated cuttings, 173 (the size of the tubers in both cases did not exceed that of a hazel nut).

These data show that bacteria produce in higher plants formative processes by means of their metabolites, similar to those produced by the action of pure preparations of phytohormones [5].

The activating effect of bacteria is manifested on entire uninjured plants as well. Bottomley [2] and Clark [3] report that *Lemnae* develop better if bacteria are present in the nutrient solution. In our own experiments bacteria treated pine-seedlings grew better than the control ones. These seedlings treated with a culture of *Pseudomonas fluorescens* (strain 30) reached by the autumn, *i. e.* on the 5th month of growth, both in pots and in the field, an average height of 9.2 cm and the length of their needles averaged 7.5 cm; the respective figures for the controls being 5.9 and 3.0 cm. The stems of the treated seedlings were thicker, their needles greener and the plants looked more wholesome than the control ones.

Table 2

Influence of Bacteria on the Rooting of Lemon Tree Cuttings

(Registered 35 days after planting)

	Time of appearing of roots	Number of roots per 1 cutting	Total length of roots (cm)
Control	12	5	7.5
Azotobacter chroococcum	8	8	13.0
» *vinelandii*	6	12	24.0
Pseudomonas fluorescens	9	25	23.0
» *aurantiaca*	12	7	10.3
Rh. meliloti	6	17	18.5
Achromobacter	10	6	8.3

Wheat seeds, treated with bacteria, germinated and developed more quickly and produced a higher yield than the controls. We tested the most active strains of bacteria in field and laboratory during 3 years and obtained a yield increase almost in every case. This increase averaged 15—25 per cent for wheat; 12—17 for beet, 15—18 for cotton; 16—25 for clover and alphalpha.

As may be seen from the above; the bacteria tested by us produce a beneficial effect on higher plants by means of their metabolites. They enhance the growth and development of the plants; activating the life processes of their cells. Therefore we propose to give these bacteria the name of activators.

Various bacteria produce this effect on higher plants by means of different substances and seem to do it not by means of certain individual substances; but by their complex. We feel justified in considering these substances as hormones.

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Received
28. II. 1944.

REFERENCES

[1] П. Бойсен-Иенсен, Ростовые гормоны растений, 1938. [2] D. Commissarov, C. R. Acad. Sci. URSS, XV, 457 (1938). [3] Н. Максимов и М. Гогаладзе, Изв. Батум. бот. сада. **3** (1937). [4] K. Turezkaya, C. R. Acad. Sci. URSS, XVII, 143 (1937). [5] Н. Холодный, Фитогормоны, Киев, 1939. [6] J. Bonner and S. Devirian, Bot. Gaz., **100**, 226 (1938); **101**, 491 (1939). [7] W. Bottomley, Ann. of Bot., **34**, 345 (1920). [8] N. Clark and E. Koller, Soil Sci., **31**, 299 (1939). [9] A. Hitchcock and P. Zimmerman, after Cholodny ([5]). [10] J. Lockes, G. Riker and B. Duggar, Journ. Agric. Res., **59**, 519 (1939). [11] E. Möller, Angew. Chem., **19/20**, 204 (1940). [12] N. Nielsen und Sing-Fang, Compt. Rend. Lab. Carlsberg, Ser. phys., **22** (1937). [13] W. Robbins, Bot, Gaz., **73**, 376 (1922); **76**, 274 (1923); **97**, 554 (1936); **98**, 209 (1936); **99**, 671 (1938). [14] J. L. Roberts and E. Roberts, Soil Sci., **48**, 135 (1939). [15] K. Thiman, Proc. Nat. Acad. Sci., **22**, 511 (1936). [16] P. West and P. Wilson, Journ. Bacter., **37**, 161 (1939).

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PLANT PHYSIOLOGY

A CONTRIBUTION TO THE PROBLEM OF PHOTOPERIODISM PHYSIOLOGY

By A. I. POTAPENKO

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It is well known that the light conditions required by the leaf are not the same during the day or night time; hence it is evident that two phases may be distinguished in the leaf's 24-hour-day activity. If during day time the light serves to the leaf in the first place as a source of energy, without which no photosynthesis can possibly take place; during the night such light intensities come into play as are insufficient even to produce the lowest degree of photosynthesis. The «photoperiodic» effect of light is well known to be produced during the night-phase only, which was emphasized by N. A. Maximov (1) as far back as in 1925.

Only an assimilating leaf is apt to produce photoperiodic impulses. This has been clearly borne out by Moshkov (2). And if it is taken into account, moreover, that nobody has succeeded as yet to experimentally isolate photoperiodic impulses from the usual production of the leaf, *viz.* the assimilates, the question naturally arises: are not the assimilates (sugars, *etc.*) carriers of photoperiodic impulses? The transmission of the photoperiodic reaction from the leaves to the points of growth is, nevertheless, obviously hormonal in nature. This contradiction vanishes, however, as soon as we assume that the hormonal impulses are transformed not only by specialized substances, but by the common plastic compounds, as well. The hormones should also be believed to have been once the components of the common metabolism, *i. e.* building material, fuel or disintegration products. And it is only in the course of evolution that they have become specialized for the transporting of hormonal impulses.

During the day the leaf is assimilating carbonic acid gas. What is then the behaviour of the leaf tissue at night? Two alternatives may be advanced: there may either take place additional conversion of the assimilates produced during the day, and their transport, or else, the assimilating apparatus may undergo some changes which tell upon the character of the work produced during the next day. In order to shed light upon this question, the following experiment has been carried out.

Under experiment was *Bidens tripartitus* L. which answers to a curtailing of the day by a considerable increase in its development rate. The plants transferred from natural conditions were in the state of four developed leaves. After the plants took root and reassumed their growth, they were divided into three separate groups, comprising 7—8 plants each; the experiment was started on June 4, 1942.

The first set received full natural light which made up 18 hours throughout the experiment, including morning and evening twilight hours.

The second set was given alternating long and short photoperiods in the following order: a long natural day with full illumination (which it was given together with the first group); then followed a short natural night. After this since the morning of the next day until 1 p. m. the plants received a reduced light, insufficient either for the set-in of blossoming, or for growth; since 1 p. m. until the next morning they were given a long night, which was followed by a long natural day again; and so on.

The third set received a continuous short day, since morning till 1 p. m., the illumination being reduced (the plants were kept under a shadowy tree). The plants of the second set were also transferred there every second day.

After a certain period of time the plants of the third set showed an excessive growth, they lost their colour and developed no new leaves. In the subsequent part of them perished because of light deficiency. 20 days after the beginning of the experiment, on June 24, the plants of the second set were found to have developed buds, and by July 8 all the plants were blossoming. Neither the controls (first set), nor the plants kept under natural conditions have produced any bud by that time.

Thus, within the second set there was observed an acceleration of development; this acceleration was as intense as that usually obtained in case of the short 10-hour-day, under which the behaviour of *Bidens tripartitus* L. had been studied: as soon as they were taken under experiment, the plants ceased forming new leaves, developing only those which have already been laid down by the start of the test.

The plants of the second set were found to produce the major part of assimilates when put under long-day conditions (up to 18 hours), followed by a short night. When the long day was made to alternate with a short one, the assimilation was so weak that the plants did not only fail to set blossoms, but their vital activity was badly affected (control, third set); yet, the intensity of illumination was quite sufficient to produce a «photoperiodic» effect.

Natural short night (about 6 hours) applied after the day-phase of photosynthesis, failed to enable the plants of the second set to form growth-accelerating impulses. This should be taken to mean that the phenomenon studied here was not due to the conversion of the assimilates and their transport. The long night (about 14 hours) necessary for a rapid development of a short-day-plant, was brought about prior to the day-phase of photosynthesis. Hence it may be inferred that it is the assimilating apparatus itself which undergoes some changes during the night.

Plant physiologists are well aware of the fact that to put a leaf under conditions of continuous illumination is not to make it assimilate carbon dioxide continuously. As shown by Smirnov (3), algae under conditions of the polar day periodically discontinue their photosynthetic activity, though both illumination and temperature seem to be favourable for the latter.

The following hypothesis seems to the author to account for the mechanism of the photoperiodic reaction. Photosynthesis is necessarily accompanied by phenomena of a reduced working ability of the chloroplasts; the recovering by the chloroplasts of their working ability is a process which requires time and energy expenditure on the part of the plant. In plants which give a photoperiodic response, the restitution of the working capacity of the chloroplasts takes place during the night when there is a standstill in their functioning. In this way a maximum productivity of the chloroplasts takes place during the day, for then they are not engaged in any restoratory work. The latter proceeds during the night-phase, provided light conditions are favourable. There are such plants as require the elimination of light (short-day-plants), such as are indifferent to light conditions during the night-phase, provided the day period is sufficiently long and makes up no less than 15—18 hours (long-day plants).

The conditions under which the night-phase of recovery of the working capacity of the assimilatory apparatus proceeds during the night-phase are responsible for the working potency displayed by the chloroplast during the next day or even in the course of several days (photoperiodic after-effect). The working state of the chloroplasts tells upon the «photoperiodic» properties of the assimilates; and this affects in turn the course of the form-building processes going on in the points of growth.

Thus, the processes leading to the production of photoperiodic impulses are in no direct relation to photosynthesis; however, in the subsequent, they may affect the course of photosynthesis as well as the properties of the assimilates.

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REFERENCES

[1] Н. А. Максимов, Труды по прикл. бот., ген. и сел., XIV. 5 (1925). [2] Б. С. Мошков, Сов. бот., № 4 (1940). [3] В. А. Смирнов, Изв. Росс. гидрол. ин-та, № 8 (1924).

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PHYSIOLOGY

ON THE MECHANISM OF VALSALVA'S EXPERIMENT

By A. M. DAMIR

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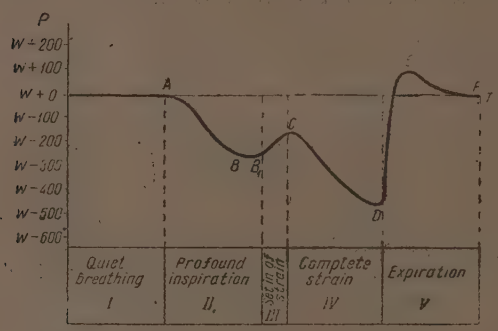
1. As far back as in 1704 Valsalva [1] invited general attention to a most simple procedure for cleansing the middle ear. Since that time and until nowadays this procedure which has after its inventor been christened the «experiment of Valsalva» (sometimes it is also called the «Pressatmung», after Bürger), has often served as a subject for investigation, considered independently of its original purpose [2—15]. The procedure consists in the following. The person under test is first invited to inspire as deep as possible, then, having either completely shut his glottis, or else tightly closed both his nasal and oral apertures without shutting the glottis, the patient strains his expiratory musculature, thus reducing the intrathoracal space as much and for as long a time as possible. It stands to reason that by doing so the air in the lungs becomes strongly compressed, both in the thorax and in the abdomen. And as the thorax and abdominal cavity are media consisting of tissues endowed with a different elasticity, the pressure also varies at the different points of this medium and at different time.



Some authors endeavoured to obtain manometrical data for the bronchi, oesophage, stomach, rectum and large intestine. Until this moment there is no essential disagreement among the authors concerned with the problem. They begin to be at variance since the very point where they try to figure out the complex influence these pressures produce upon blood circulation. It should be emphasized in this place that up to the present we possess but indirect evidence of the fact that it is the internal organs of the thorax that become devoid of blood. And yet the «experiment of Valsalva» is being reproduced an infinite number of times daily, since any short but intense muscular strain connected either with sport or labour, both physiological (say, the travail) and pathological (for example, coughing) are nothing else than a Valsalva experiment either in its pure form, or somewhat modified. It is but natural, therefore, first: experimentally to reproduce with utmost precision the phenomena associated with Valsalva's experiment; secondly, to try and qualitatively inquire into the mechanism of the experiment; thirdly, to make attempts accurately to evaluate the masses of blood displaced by it.

2. Experimental Method. Seventeen men sound from the clinical point of view, *i. e.* persons with no complaints of any ailment either in the past or in the present, have been investigated. The patient to be tested was invited to take place on the platform P of our apparatus ([16]). After having taken as deep a breath as possible, the patient tried to raise by an expiratory strain the mercury column in the manometer to a maximum height. The weight variation p of the cephalic part P_h of the platform P was recorded diagramatically. In accordance with the character of Valsalva's method we have subdivided the whole period of time taken by our test into five stages;I; II; III; IV and V. The figure contains a curve illustrating the variation in the arithmetical mean of the weights p of all the cases tested. It should be pointed out that this averaging went by no means to smooth-out peculiarities of the separate stages of Valsalva's experiment. The shape of the averaged curve remains therefore quite illustrative of the separate instants of the test in each individual patient.

3. Analysis of the Curve and Mechanism of Valsalva's Experiment. Let us take as our starting point the fact that the movement of the diaphragm together with the underlying heavy organs, the liver and the spleen, affects strongly the gravity centre of the body, Z. During the stage I («quiet breathing») no important displacement of the heavy masses takes place, Z being relatively stable. Towards the stage II («profound inspiration») the inspiratory movement of the diaphragm presses the liver downward, as a result of which P_h becomes lighter. This accounts for the monotonous slope of the AB section of the curve. At this stage the patient arrests for a few seconds his breath at the point of a profound inspiration; the blood has still experienced no particular pressure; all the organs and hence Z; too, being fixed in place. This accounts for the stationary character of the BB_1 section of the curve.

Stages III and IV are the initial and ultimate phases of a single long interval of strain. During this interval all the organs are immobile. It is only the blood which is displaced; and its shifts are responsible for the shape of the B_1D section of the curve. In the stage III («set-in of strain»); which is of shortest duration (2 seconds only) the B_1C section of the curve rises monotonously. This should be taken to mean that P_h grows heavier and; consequently; there is an afflux of blood to the upper part of the body. Now we have to find out the part of the body from which it comes. It should be noted that at the stage III the intraabdominal pressure increases rapidly; pressing the liver to the dome of the diaphragm. Let us also take into account that any analogy borrowed from the domain of hydrostatics is entirely out of place here. To our case only such laws of strain hold good as refer to bodies endowed with different elasticity and contained in an elastic medium. In the particular case of stage III the liver; as a body with a smaller elasticity coefficient; when pressed to the diaphragm; is more liable to strain than the diaphragm. The effect of pressure is to press out of it the blood, as of the flabby *venae cava* and *illiaca*. The whole mass of blood dislodged is rapidly supplied upwards on to the heart. This accounts for P_h becoming heavier for a short while. As a result, the heart must increase in volume during stage III. Literature, however, contains no information on this point. This may be explained by the fact that the phenomenon referred to above is of too short duration and is often overlooked, unless one is beforehand aware of its occurrence. Extreme precision and assiduity of observation are required in order to record it. The phenomenon has been noticed by Nolte ([15]) who has dropped a cursory remark to the effect.

During the stage IV («full pressure») it is the organs which possess the lowest elasticity coefficients that are the most susceptible to deformation: the lungs, the thin-walled veins of large and medium diameter, the readily distensible wall of the auricles. The elastic ventricles and arterial trunks and aorta, being under a high internal pressure, are less affected by the intraabdominal pressure. As a result, anaemia of the lungs, of the heart itself, of the liver and spleen sets in. The blood recedes along the arterial trunks towards the periphery, penetrates through the capillaries into the veins and cannot return to the heart, because of the high pressure constricting the trunks of *venae cava*, *illiaca* and *subclavicularis*.

Thus, the heart, the *venae cavae* and the portal system become poor in blood. At the same time the veins of the limbs and of the head are overfulfilled. And as the capacity of the veins of the lower part of the body exceeds that of the upper one, Z is monotonously shifted downward. Hence the monotonous decrease in the CD section of the diagram. Within this section there cannot possibly be any interval of stability, since the suddenly increased pressure in the upper part of the body cannot press out the blood of the trunk otherwise than gradually. It is important to point out in this place that in the case of Valsalva's experiment the blood is by no means pressed out of the heart, but rather supplied to it in smaller quantities. The receding of the blood from the heart proceeds in the following way: owing to the tonicity of the arterial system and to the uninterrupted work of the heart, the blood recedes first of all from the right heart, then from the lungs; after which it leaves the left heart and the large arterial trunks leaving void the aorta and the pulmonary arteria. In an X-ray photograph the bundle of large vessels is seen to become narrower. As a result of all that has been said here, the abdominal cavity and the heart become poor in blood. The important circumstance that the heart's volume decreases not because of the blood being «pressed-out» of it or prevented from entering the contracted ventricles, but as a result of an arrested blood supply along the veins of the systemic round; is also witnessed by the fact that the weight of P_h during stage IV has been found to drop to the same extent in perfectly sound persons and in persons who have hypertrophied left ventricles, although the walls of an hypertrophied heart, having a greater elasticity coefficient, should more successfully resist to the relatively low pressure applied in Valsalva's experiment. The conclusion to be drawn is that in persons who are accustomed to body exercise and have a working hypertrophy of the ventricles, circulation is subject to equally important changes as in people who are accustomed to manual labour. It is not amiss to note that, contrary to Bürger's opinion, in the stage IV the blood is not delayed in the lungs; but leaves them instead. This is evidenced by the considerable displacement of Z, which is recorded at this stage by our apparatus.

During the stage V («expiration») the weight of P_h increases rapidly. From two to four contractions of the heart are sufficient in order that the needle of the balance R resume its original position. This points to the extréme rapidity with which the blood rushes from the overfilled extrathoracal veins; first, to the evacuated trunks of the large body veins, then into the right heart and the lungs; and, finally, into the left ventricles, aorta and arterial trunks.

In concluding, it should be noted that Valsalva's experiment is the only procedure of a total evacuation of the heart practicable on a live man. It is sometimes believed to involve a certain risk; and some of the cases of sudden death occurring during intense body overstrain have been supposed to be due to the mechanism operative in Valsalva's experiment.

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REFERENCES

[1] A. M. Valsalva, De aure humana, 1704. [2] Fr. Riegel u. L. Franck, Arch. f. kl. Med., 17, 401 (1876). [3] K. Baas, Münch. med. Woch., 50, 2057 (1903). [4] Fr. Kraus, D. Med. Woch., 31, 52 u. 90 (1905). [5] Ledderose, Mitt. aus d. Grenzgeb. d. Med. u. Chir., 15, 355 (1906). [6] A. Politzer, Gesh. der Ohrenheilkunde, Stuttgart, S. 230, 1907. [7] E. Bruck, D. Arch. f. kl. Med., 91, 17 (1907). [8] M. Bürger, Münch. med. Woch., 68, 1006 (1921); Kl. Woch., 5, 777 (1926). [9] A. Pongs, Berlin, 1923. [10] E. Mosler u. Balsamoff, Kl. Woch., 3, 491 (1924). [11] E. Griems, Arch. of int. Med., 47, 876 (1931). [12] O. Nordenfelt, Acta Med. Scand., 82, 465 (1934); 93, 297 (1937). [13] A. Bittorf, Fortsch. a. d. Geb. d. Röntg., 9, 28 (1906), [14] E. Klaus u. D. Albert, D. Arch. f. kl. Med., 182, 447 (1938); 183, 315. [15] F. A. Nolte, Fortsch. a. d. Geb. d. Rönt., 50, 211 (1934); 56, 20 (1934). [16] A. M. Damir, C. R. Acad. Sci. URSS, XLIV, No. 2 (1944).

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